Global Earth Observation System of Systems: Global Land Observing System Integrated Water Cycle Monitoring System

NASA-ROSES 2005: WaterNet Sollutions Network

Will Pozzi, Balazs Fekete, Charles Vorosmarty, Michael Piasecki, and Paul Houser

CREW Center for Research on Environment and Water

GEORGE MASON UNIVERSITY

Water Cycle Research Making a Difference

Water Cluster Meeting at ESIP Summer Session 2008

Federation of Earth Science Information Partners

Water in the climate system functions on <u>all</u> time scales: From hours to centuries

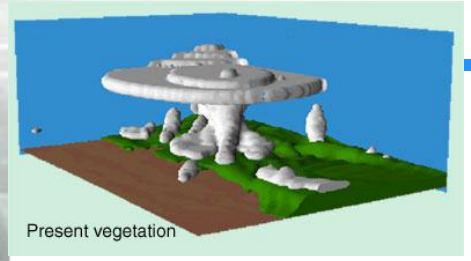
ESIP motto: “Making Data Matter”

Satellites generate data; In situ instrumentation generates data

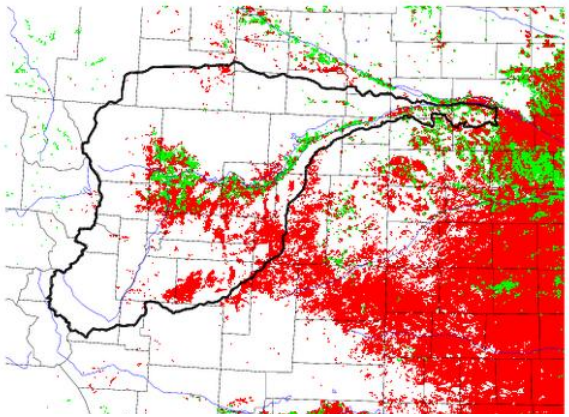
Data are needed to describe the state of the Earth system, i.e., bountiful water or disaster mode. **So data MUST be linked to applications and decision support systems.**

Common Themes Among CUAHSI, WaterNet, State-of-the-Global-Water-Cycle

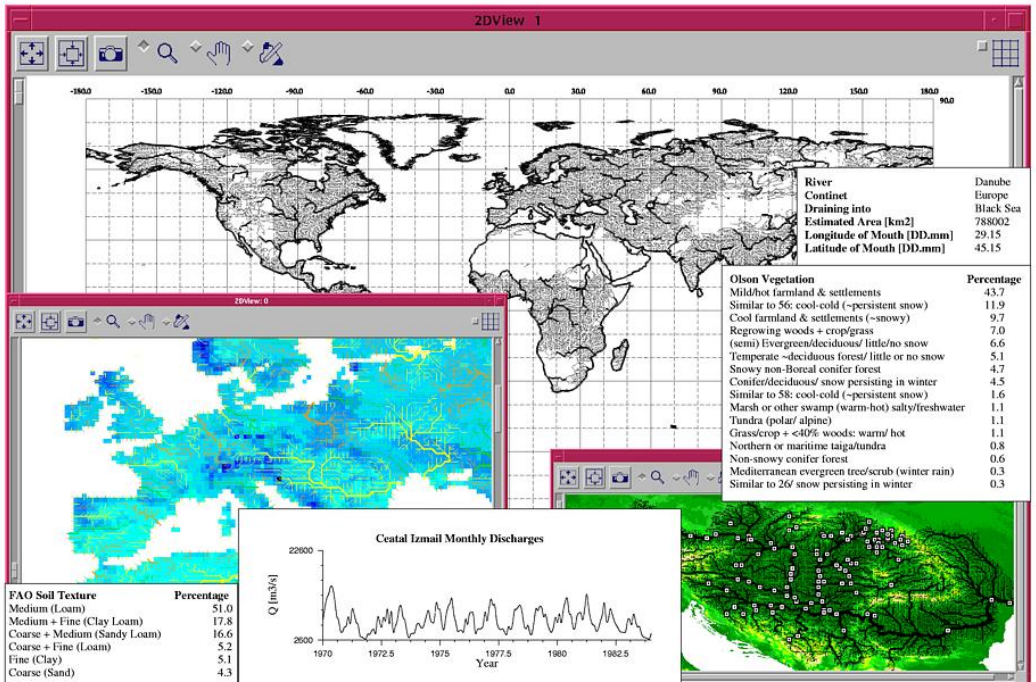
- Web Services—automate the process of acquiring data
- Model programming environment
- Framework accepting “plug in” model modules
- High-speed data transmission
- Cyber-Infrastructure (including parallel programming or cluster requirements)
- Ontology and Semantic Web to connect together variables in application services and model variables



Contributions from Earth System Science



- *In situ* networks
- Operational satellite-based monitoring of the hydrosphere
- Simulation models and data analysis tools (NWP-4DDA, GCMs, RCMs, ESMs)
- Geo-referenced social science data

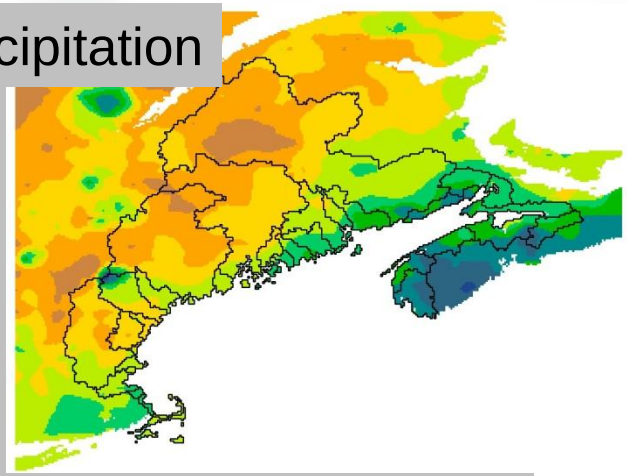


…are creating new ways to view the “global water crisis”

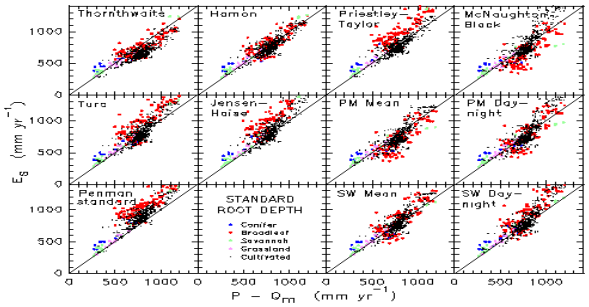
…to inform policy and improve management

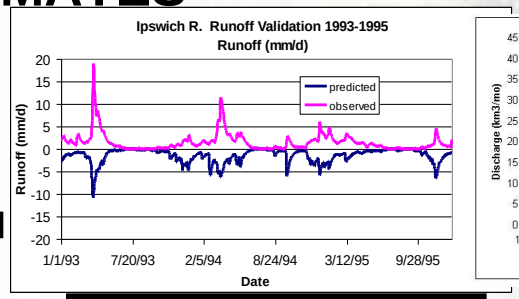
TYPICAL SCHEME TO GENERATE OPERATIONAL WATER FLUX ESTIMATES

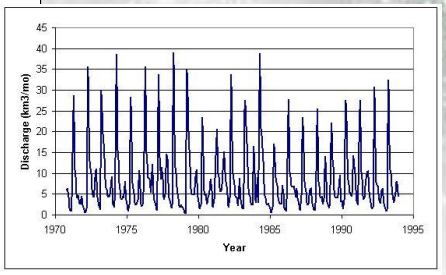
Precipitation



Evapo-transpiration

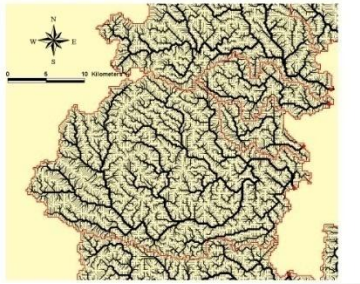




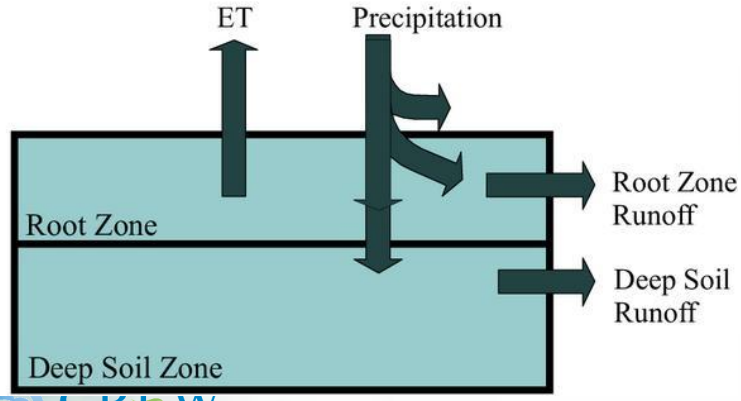


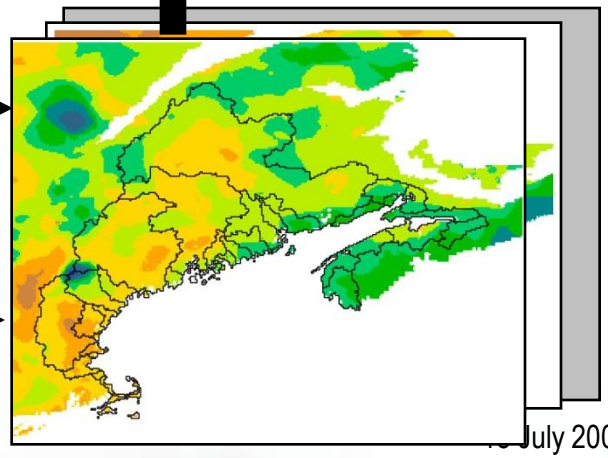
Lateral Transport

River Networks



WBM/WTM

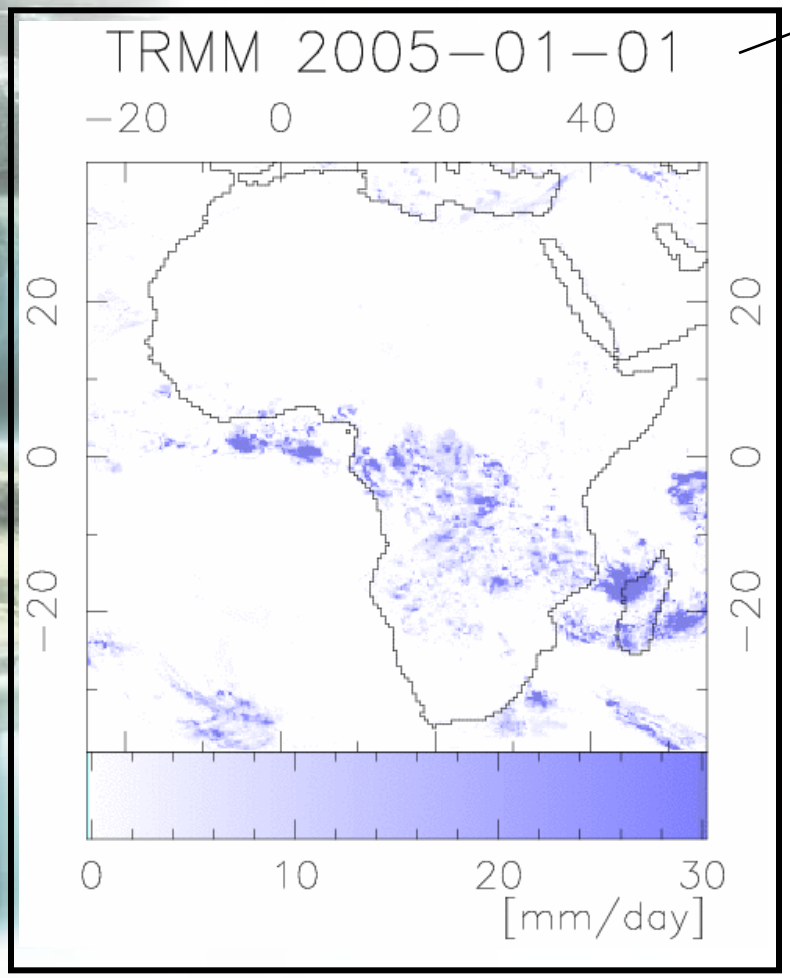




Runoff= Local Water Resource

State-of-the-Global Water System: Moving toward Operational Assessments

Rural Flood Exposure / Hazard / Damage Mapping

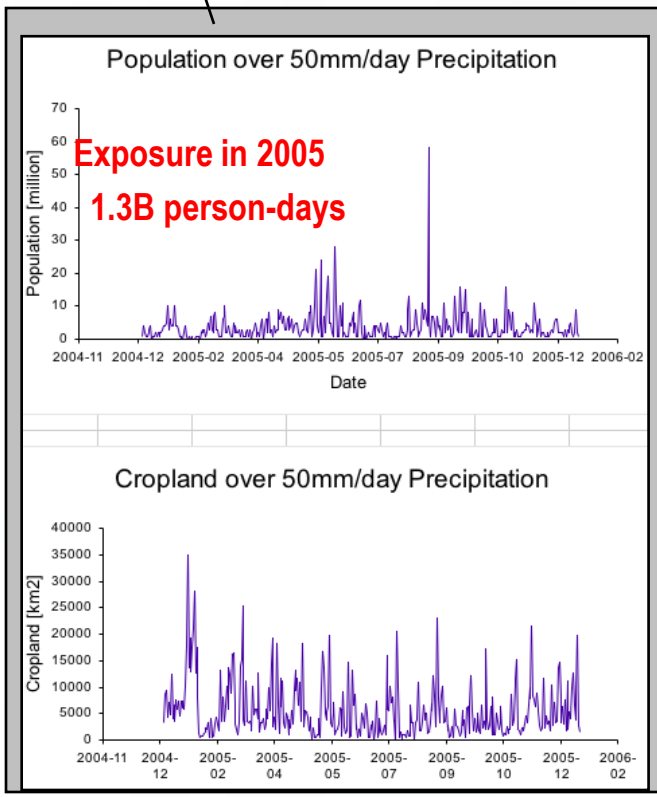


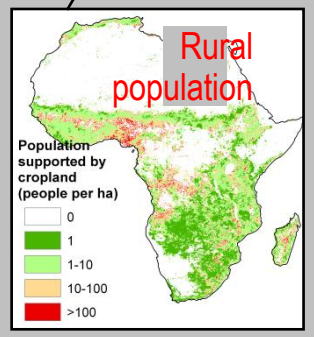
Derived Products

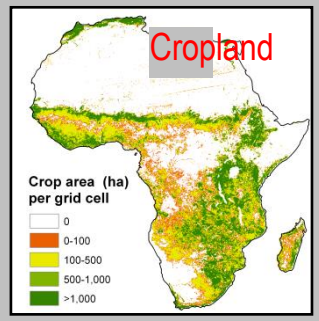
(e.g. hazard exposure)

Geospatial

Socio-economics







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GWSP Global Water System Project

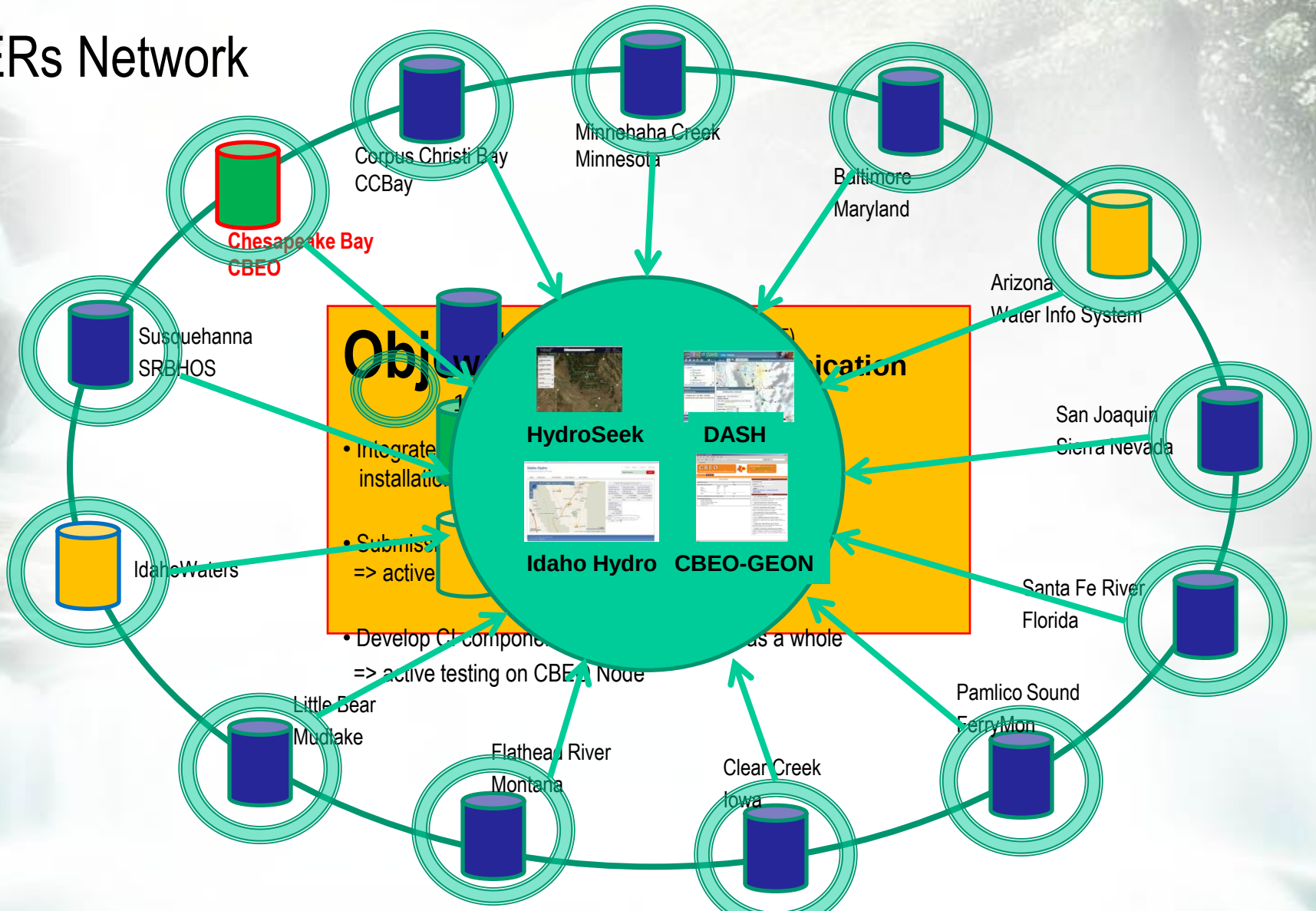
CUAHSI Contribution

Presentation Kindly Offered by Dr. Michael Piasecki, Drexel University

Waters Observatory Network

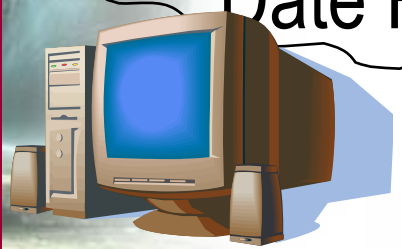
- Observe water systems
- Observe in many different contexts and for different purposes
- Have a Waters Network Information System for sharing data
  - Common language for data
  - Geographic federation of dispersed data sources through web services

WATERs Network



WaterML and WaterOneFlow

Locations
Variable Codes
Date Ranges



Client

LOAD

GetSiteInfo
GetVariableInfo
GetValues
WaterML

WaterOneFlow
Web Service

TRANSFORM

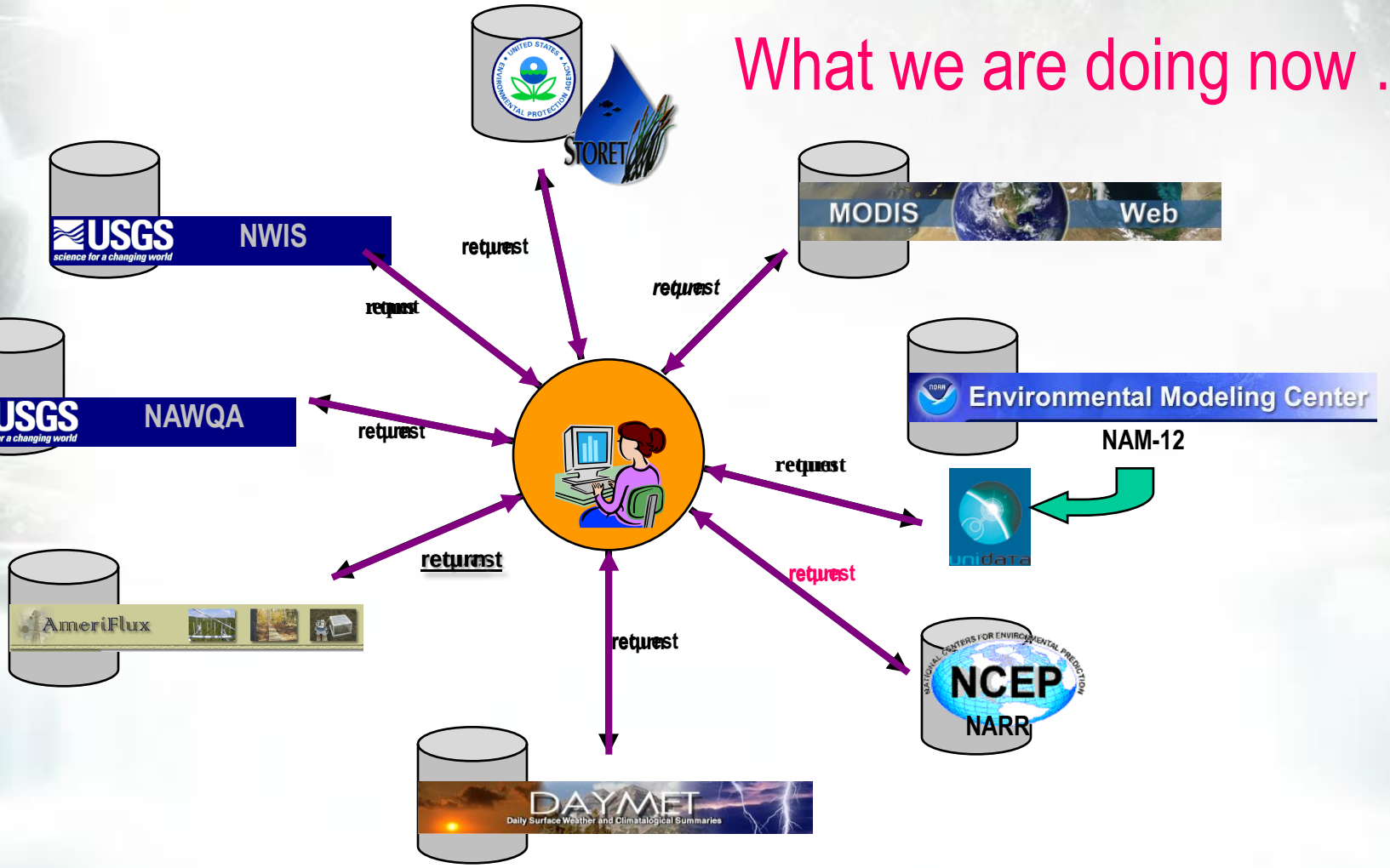
STORET
Data
NWIS
NAM
Data
DATA

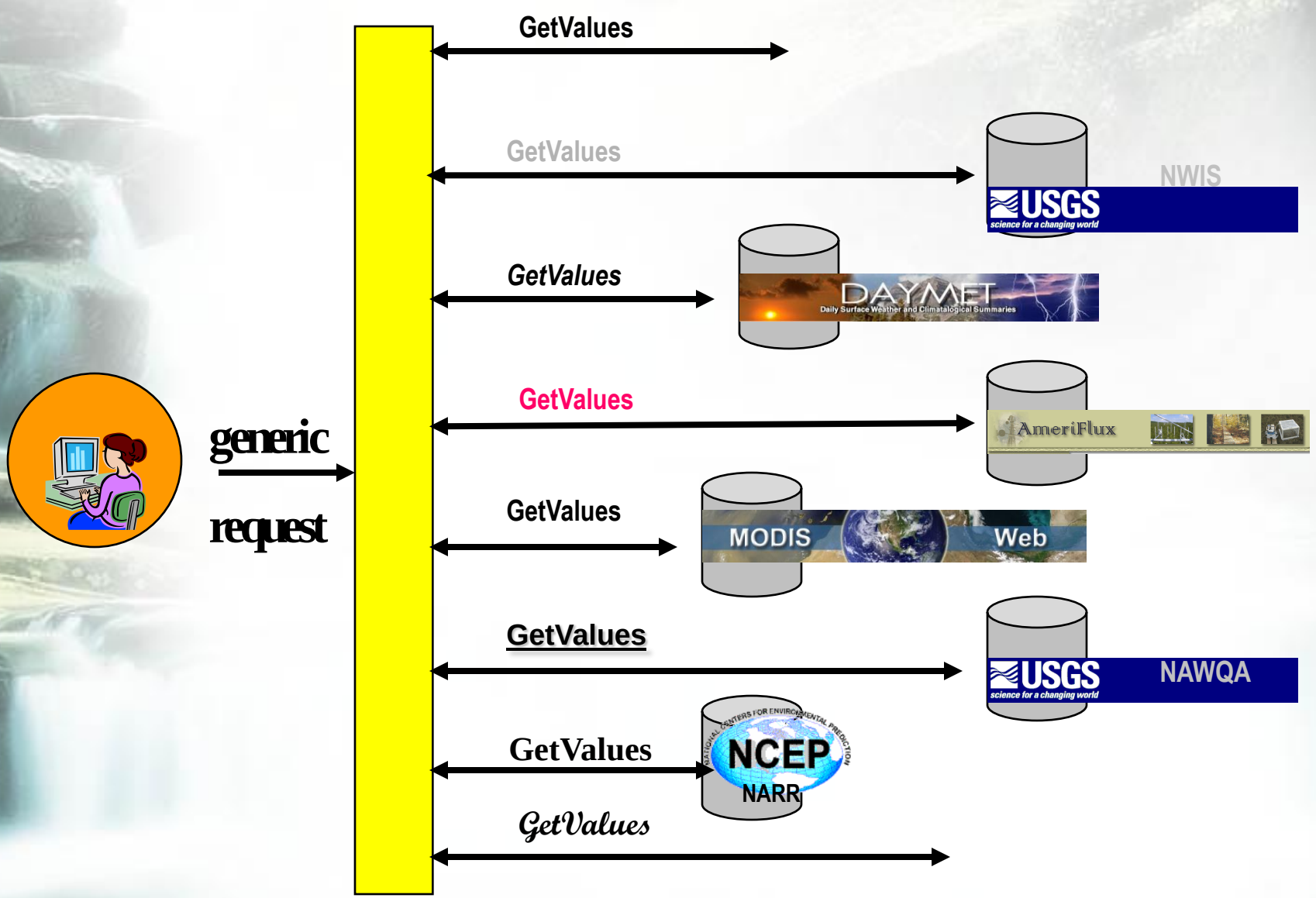
Data
Repositories

EXTRACT

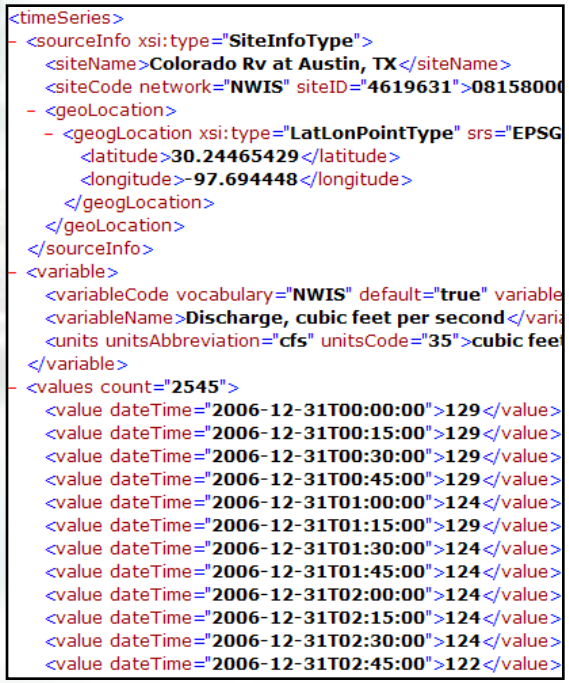
- Search multiple heterogeneous data sources simultaneously regardless of semantic or structural differences between them

What we are doing now …..




GetValues
GetValues
NWIS
USGS
science for a changing world
GetValues
DAYMET
Daily Surface Weather and Climatological Summaries
GetValues
AmeriFlux
generic
request
GetValues
MODIS
Web
GetValues
USGS
science for a changing world
NAWQA
GetValues
NCEP
NARR
GetValues

- **Syntactic mediation**
  - **Heterogeneity of format**
  - Use WaterML to get data into the same format



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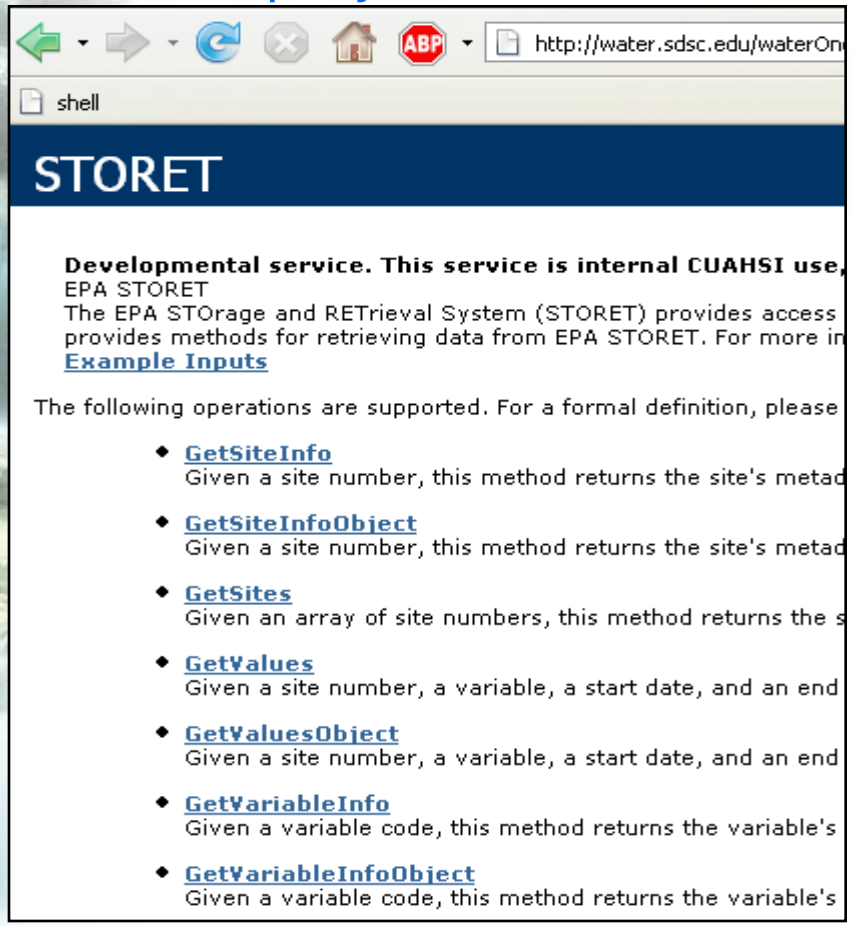
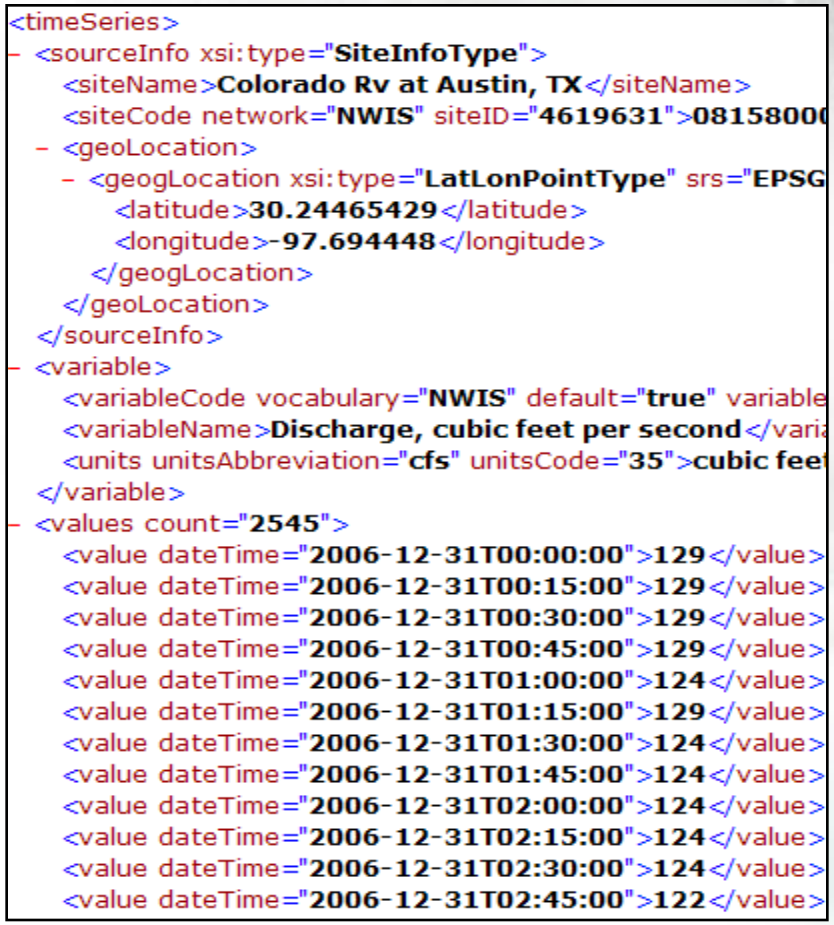
```

- **Semantic mediation**
  - **Heterogeneity of meaning**
  - Each water data source uses its own vocabulary
  - Match these up with a common controlled vocabulary
  - Make standard scientific data queries and have these automatically translated into specific queries on each data source

- Set of query functions



- Returns data in WaterML



Knowledge Base

- **OWL Ontologies**

'Escherichia coli' = 'E. coli'
'E. coli' is-a 'Indicator Organism'

'Copper' is-a 'Micronutrient'
'Copper' isMeasuredIn 'Medium'
'Medium' = {Water, Soil…}
'Micronutrient' is-a 'Nutrient'

- **Supports classification of search results**
- **Entities in the ontology are associated with measured variables in a relational database**
- **Helps solving semantic heterogeneity issues between data repositories**

Search Strategy

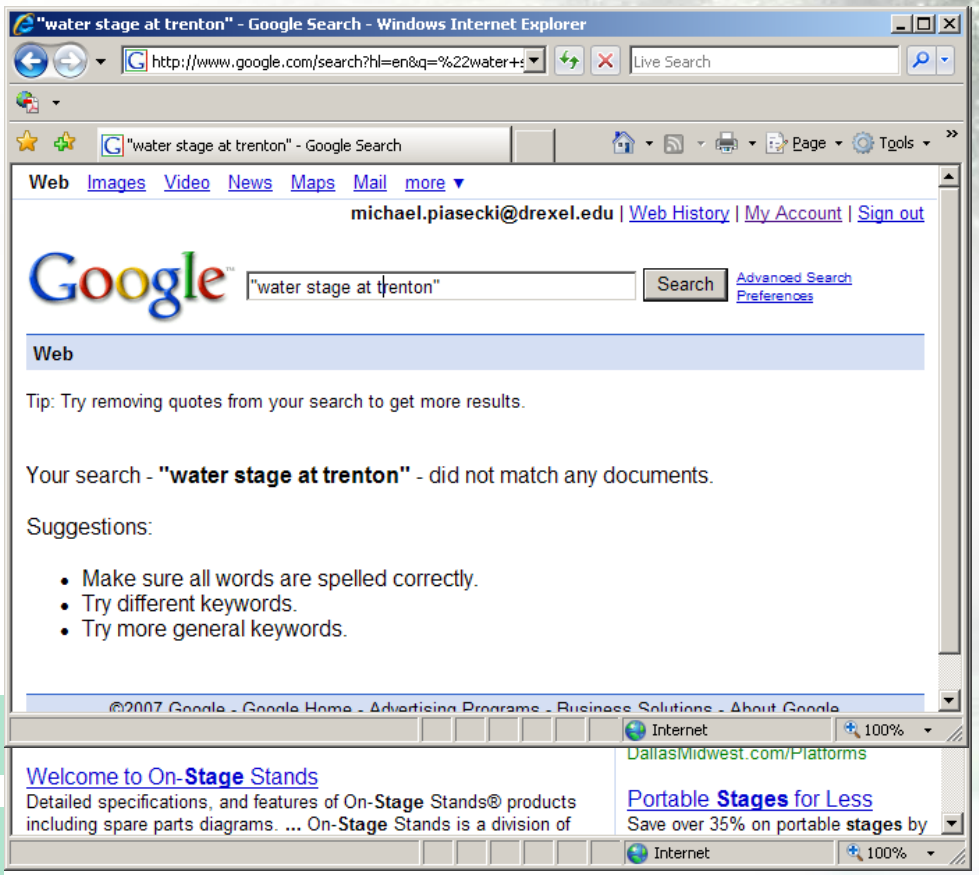
Search → Fine tune → Retrieve

rather than

Search → Retrieve

avoid 'high precision, low recall' and 'low precision, high recall'

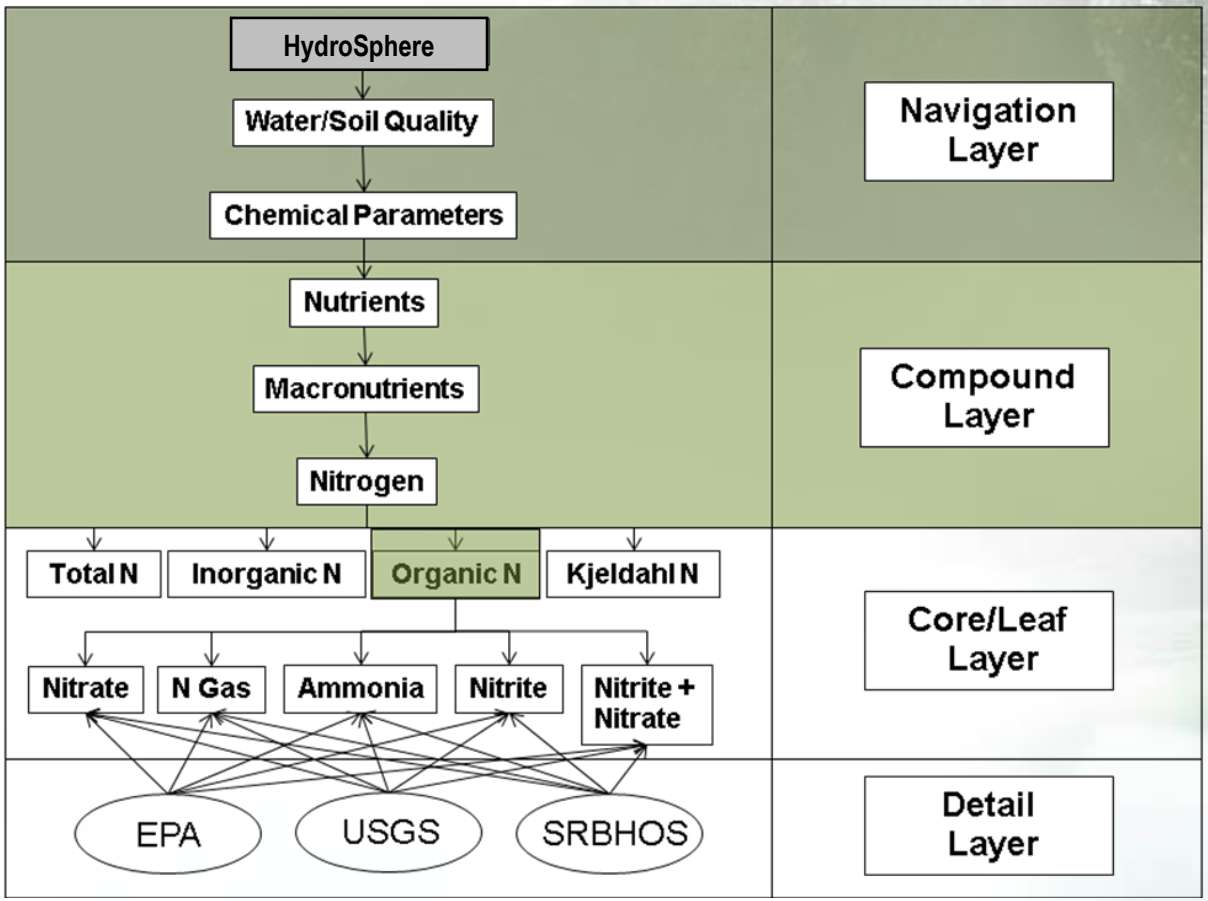
problems.



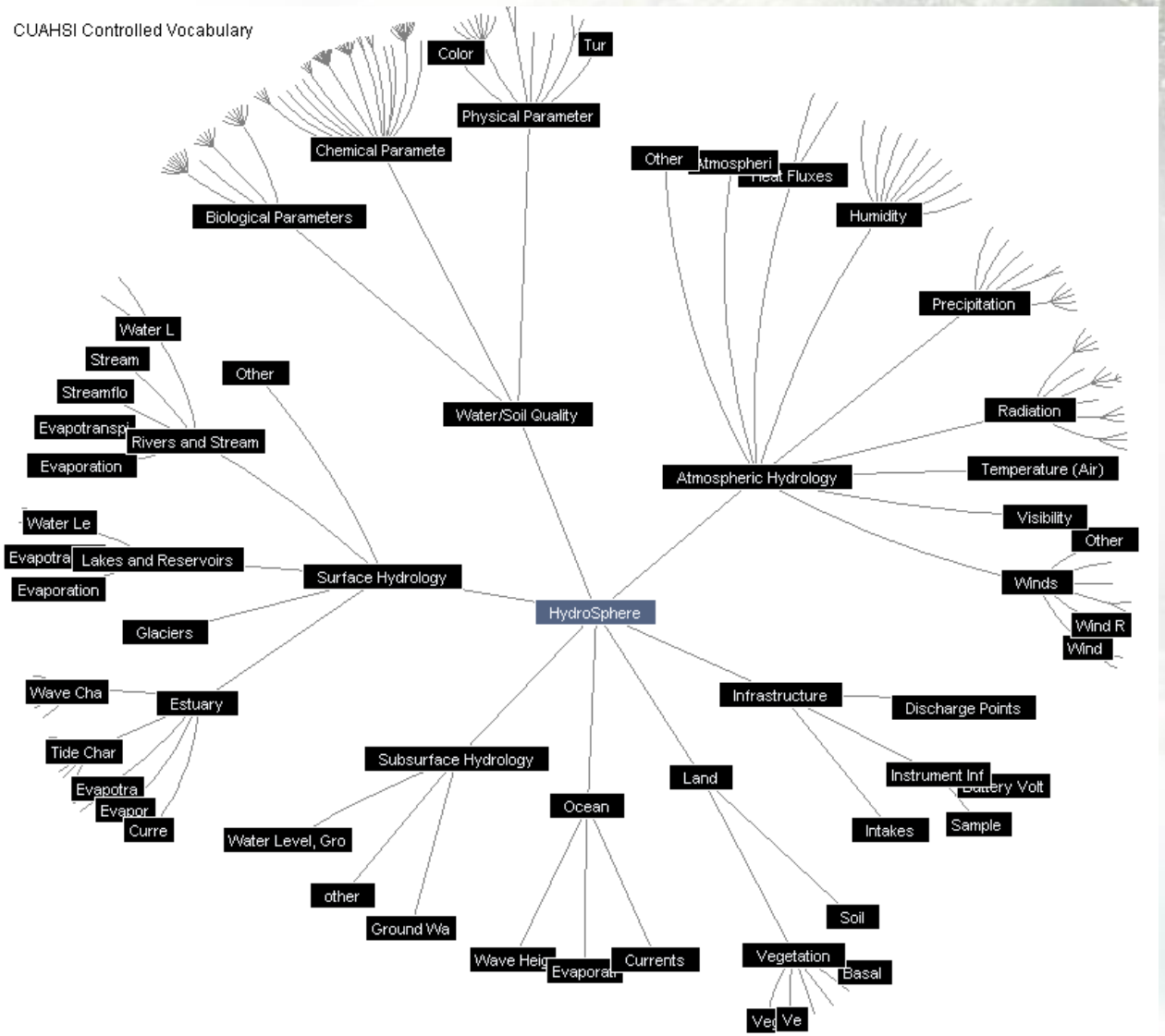
Example: Nitrogen

All Concepts in those two layers make up the pool of permissible Search Keywords

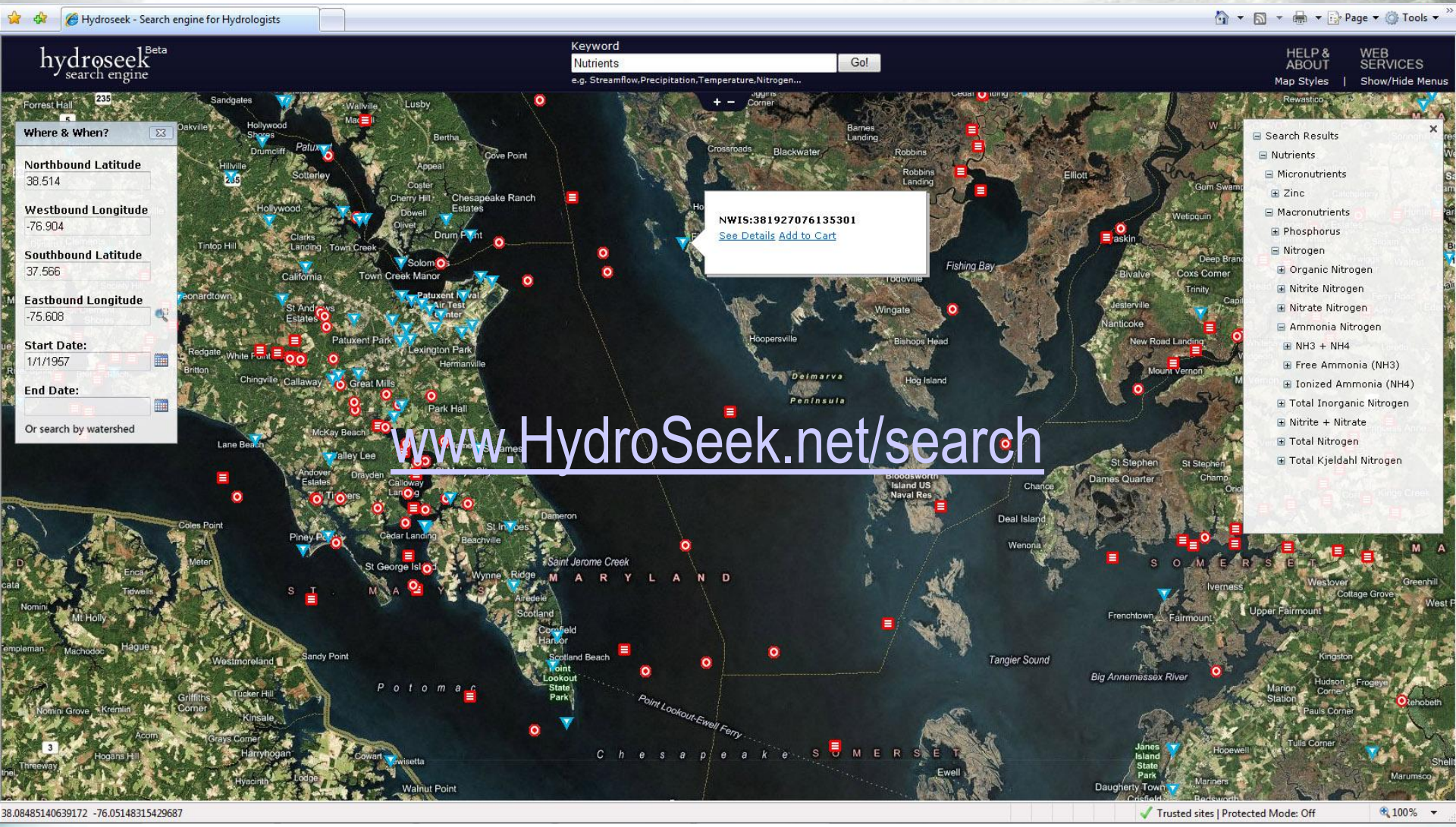
All Concepts in this layer provide the pool of permissible Tagging Targets



Hydrologic Ontology



http://hiscentral.cuahsi.org/sta


Hydroseek - Search engine for Hydrologists
hydroseek Beta
search engine
Keyword
Nutrients
Go!
e.g. Streamflow,Precipitation,Temperature,Nitrogen...
HELP & ABOUT
WEB SERVICES
Map Styles | Show/Hide Menus
Where & When?
Northbound Latitude
38.514
Westbound Longitude
-76.904
Southbound Latitude
37.566
Eastbound Longitude
-75.608
Start Date:
1/1/1957
End Date:
Or search by watershed
NWIS:381927076135301
See Details Add to Cart
Search Results
Nutrients
Micronutrients
Zinc
Macronutrients
Phosphorus
Nitrogen
Organic Nitrogen
Nitrite Nitrogen
Nitrate Nitrogen
Ammonia Nitrogen
NH3 + NH4
Free Ammonia (NH3)
Ionized Ammonia (NH4)
Total Inorganic Nitrogen
Nitrite + Nitrate
Total Nitrogen
Total Kjeldahl Nitrogen
www.HydroSeek.net/search
MARYLAND
Chesapeake
Potomac
Delmarva Peninsula
Fishing Bay
Tangier Sound
Big Annemessex River
Point Lookout-Ewell Ferry
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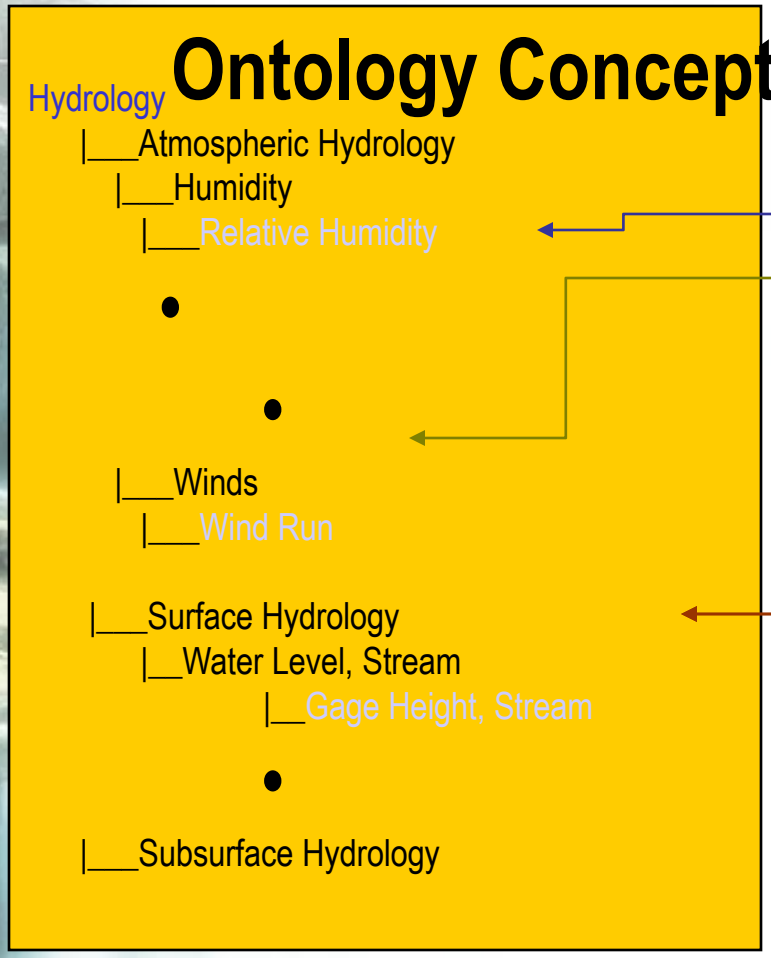

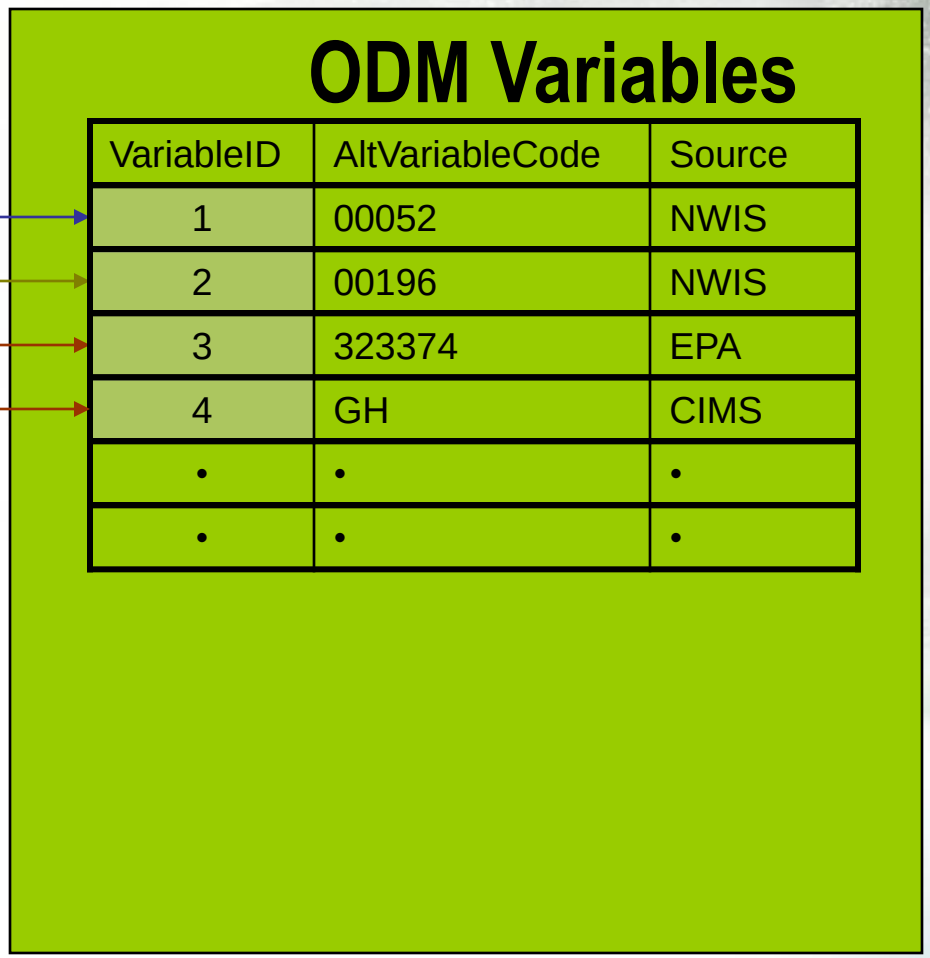

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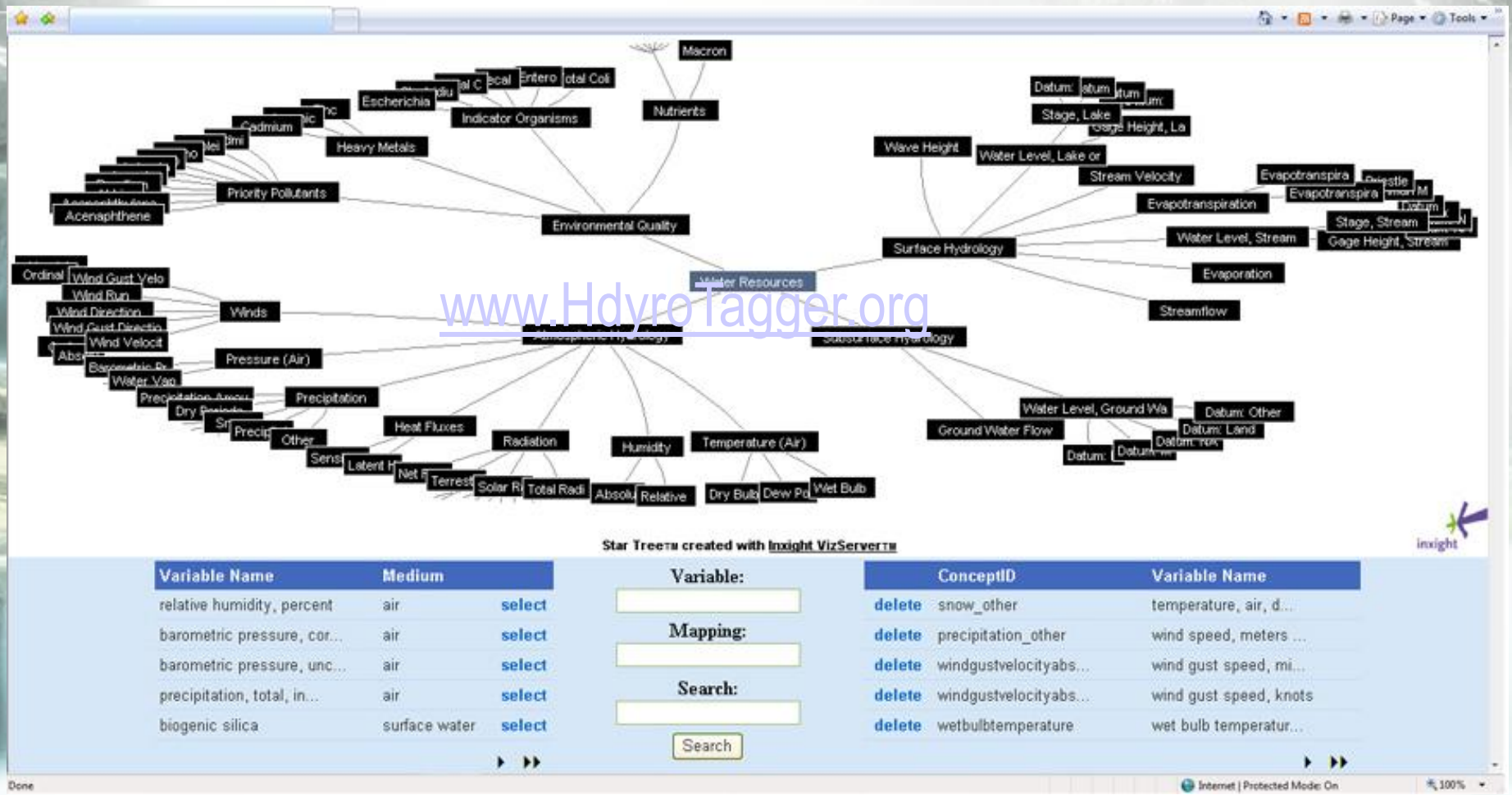
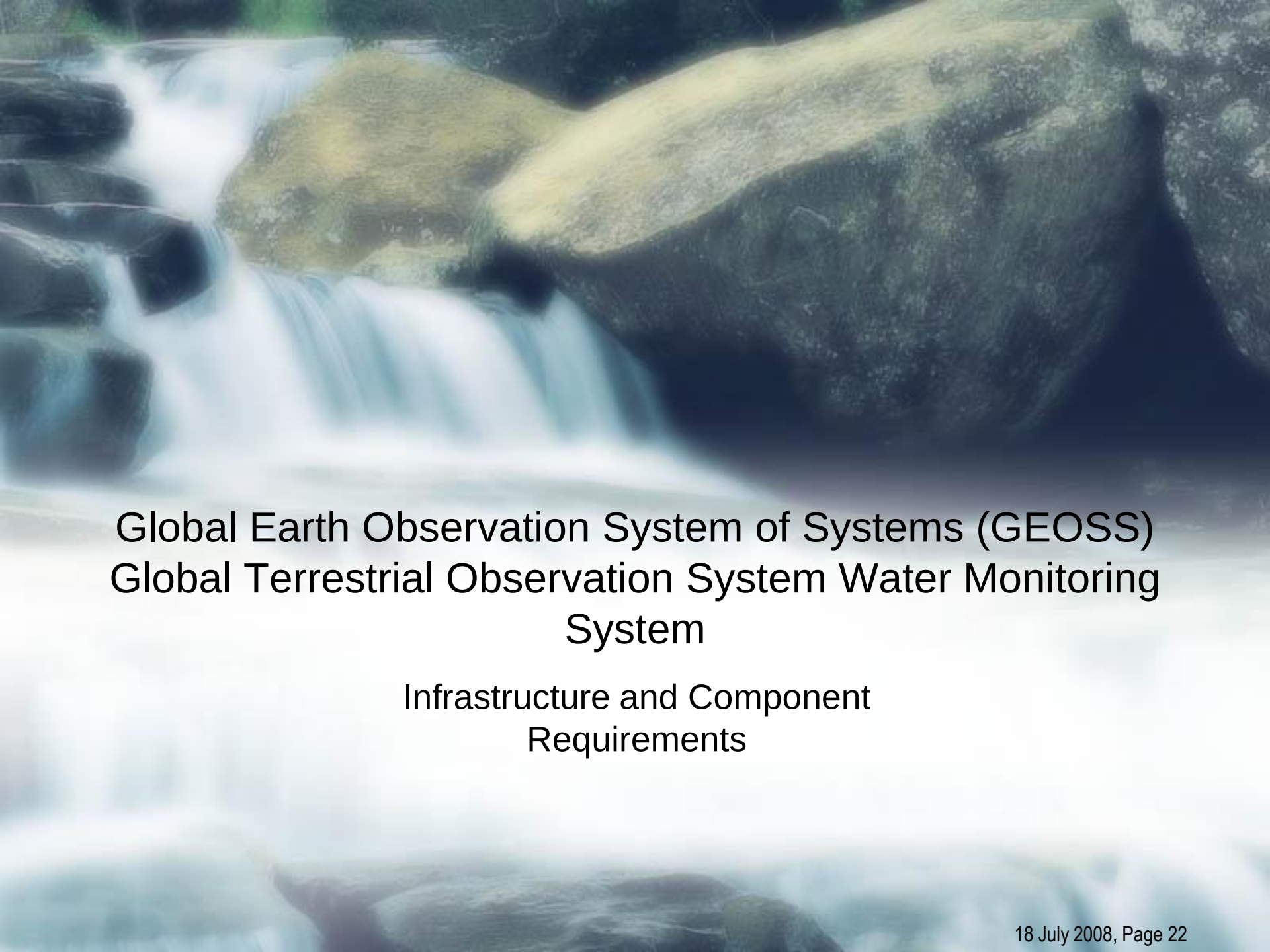
3	323374	EPA
4	GH	CIMS
•	•	•
•	•	•

Only greens are “taggable”

The Database-Ontology Link





Global Earth Observation System of Systems (GEOSS) Global Terrestrial Observation System Water Monitoring System

Infrastructure and Component Requirements

GTN-H Hosted by UNH

Global Terrestrial Network – Hydrology (GTN-H) – Home

http://gtn-h.unh.edu/PHP/index.php

GTN-H

RBIS – World | Global Terrestrial Netwo...

WMO UNESCO UNEP ICSU

GCOS | GTOS | HWRP

What is GTN-H? | GTN-H Partners

GTN-H

Global Terrestrial Network - Hydrology

- Sources of Hydrological Data
- Hydrological Data Products
- Data Sharing Strategies
- Expert Meetings
- Coordination
- Links
- Contact Us

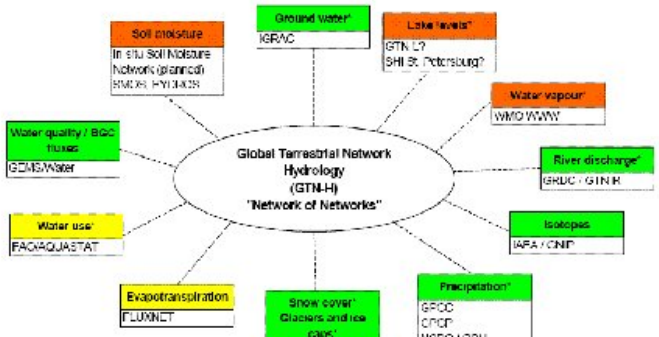
Welcome to the GTN-H

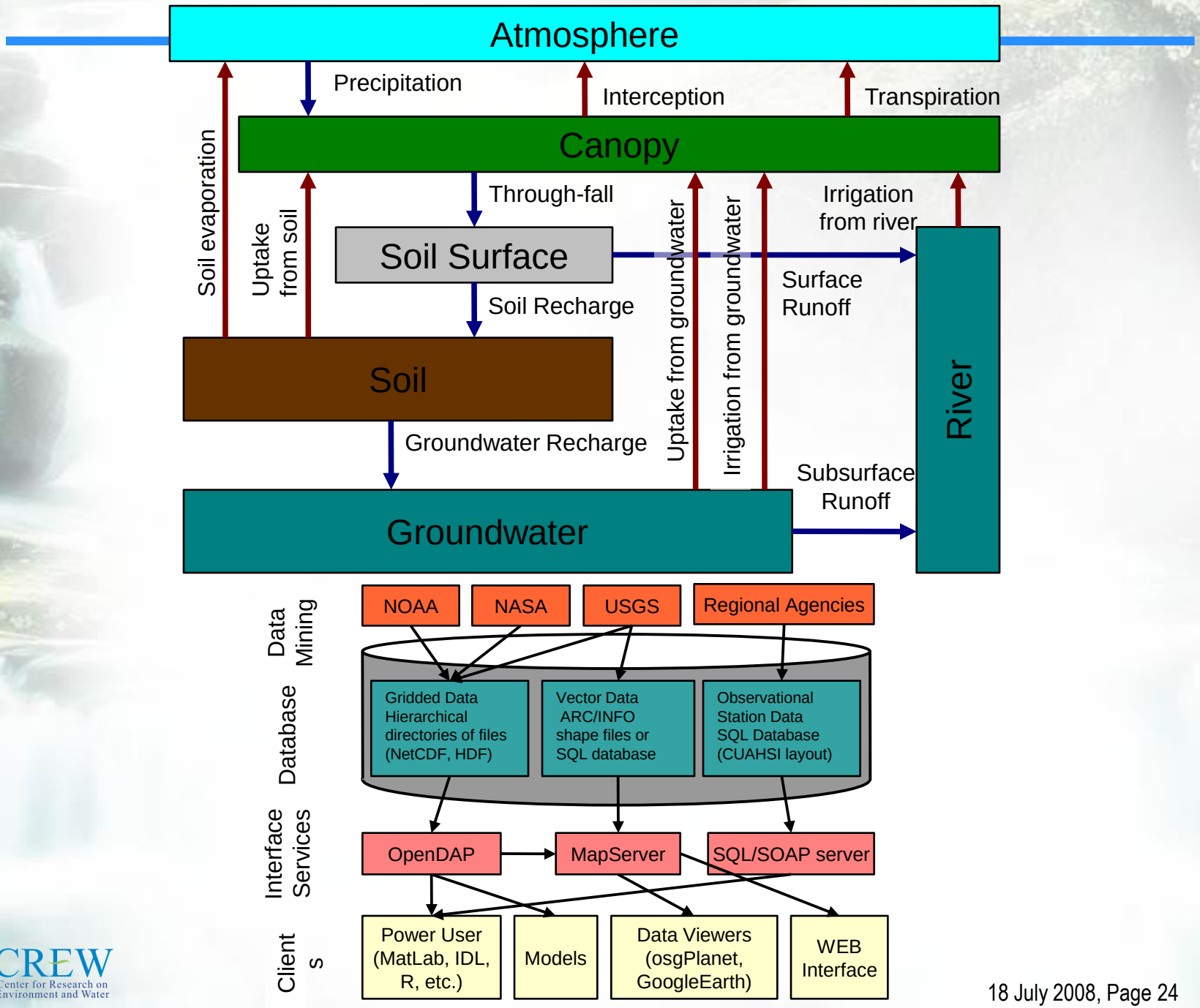
This site is a gateway to an evolving global observing system for hydrological data, known as the Global Terrestrial Network for Hydrology, or GTN-H. The GTN-H is intended to support a range of climate and water resource objectives, building on existing networks and data centres, and producing value-added products through enhanced communications and shared development.

NEW! Report of the 2nd GTN-H Coordination Panel Meeting
Koblenz, Germany, 4 - 5 July 2005
GCOS-101

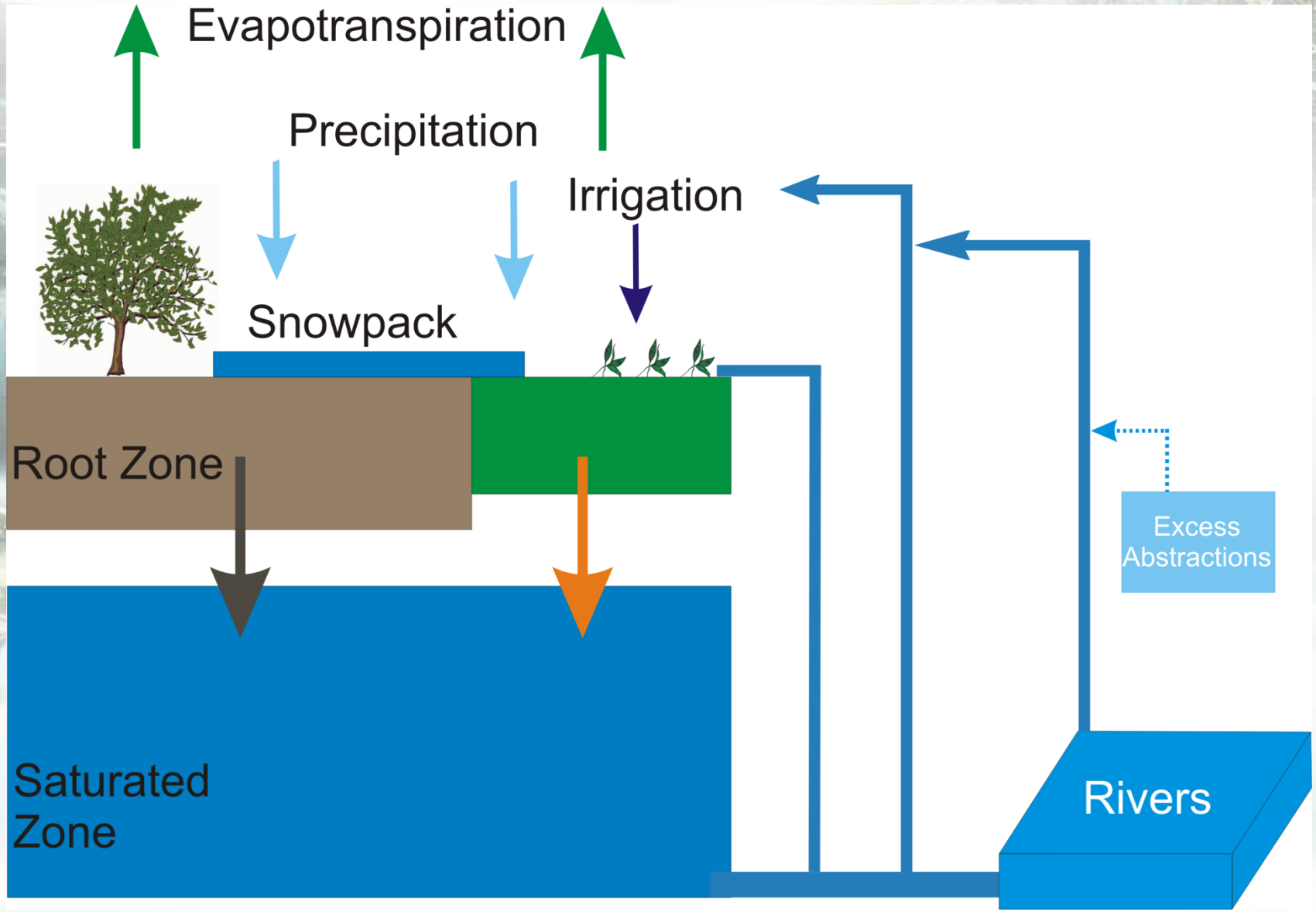
Please click on image to enlarge

Fig. 1: GTN-H Configuration (15 July 2005)

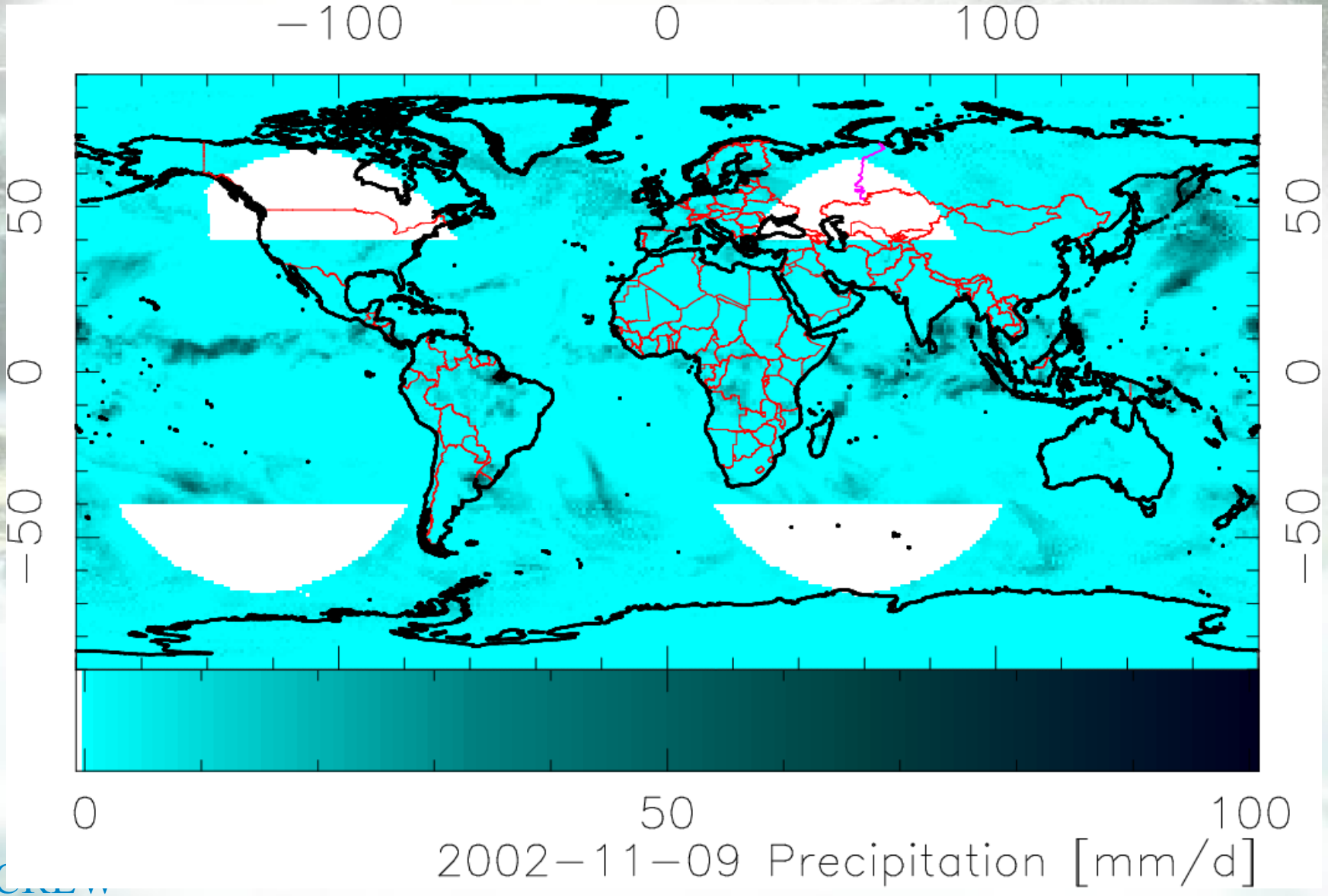



Atmosphere
Precipitation
Interception
Transpiration
Canopy
Soil evaporation
Uptake from soil
Through-fall
Soil Surface
Soil Recharge
Soil
Groundwater Recharge
Uptake from groundwater
Irrigation from groundwater
Irrigation from river
Surface Runoff
Subsurface Runoff
River
Groundwater
Data Mining
NOAA
NASA
USGS
Regional Agencies
Database
Gridded Data Hierarchical directories of files (NetCDF, HDF)
Vector Data ARC/INFO shape files or SQL database
Observational Station Data SQL Database (CUAHSI layout)
Interface Services
OpenDAP
MapServer
SQL/SOAP server
Clients
Power User (MatLab, IDL, R, etc.)
Models
Data Viewers (osgPlanet, GoogleEarth)
WEB Interface

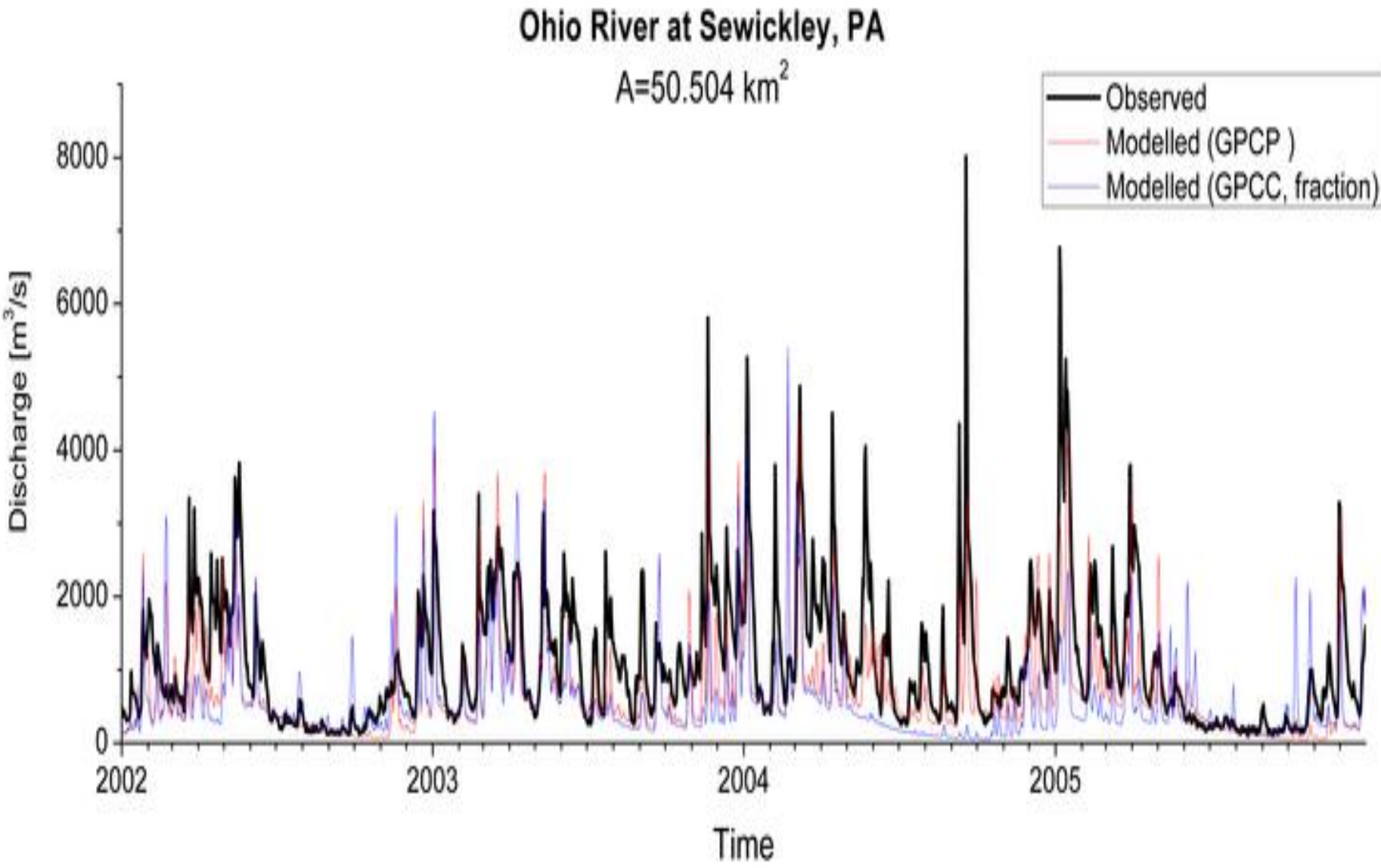
Water Abstractions in WBMplus



GPCP Daily Precipitation

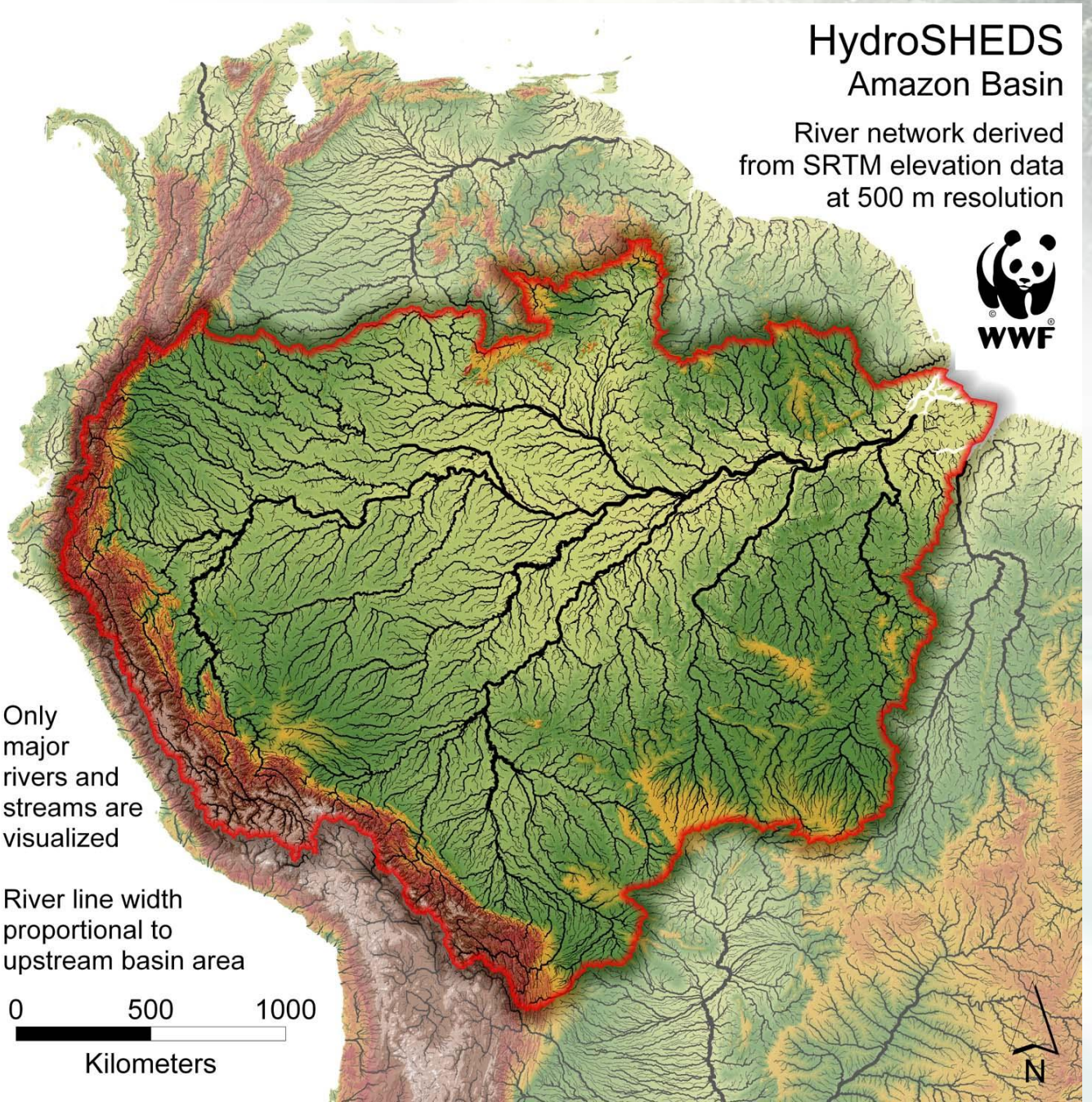


Simulated Discharge



UNH Water Systems Analysis Group

HydroSHEDS



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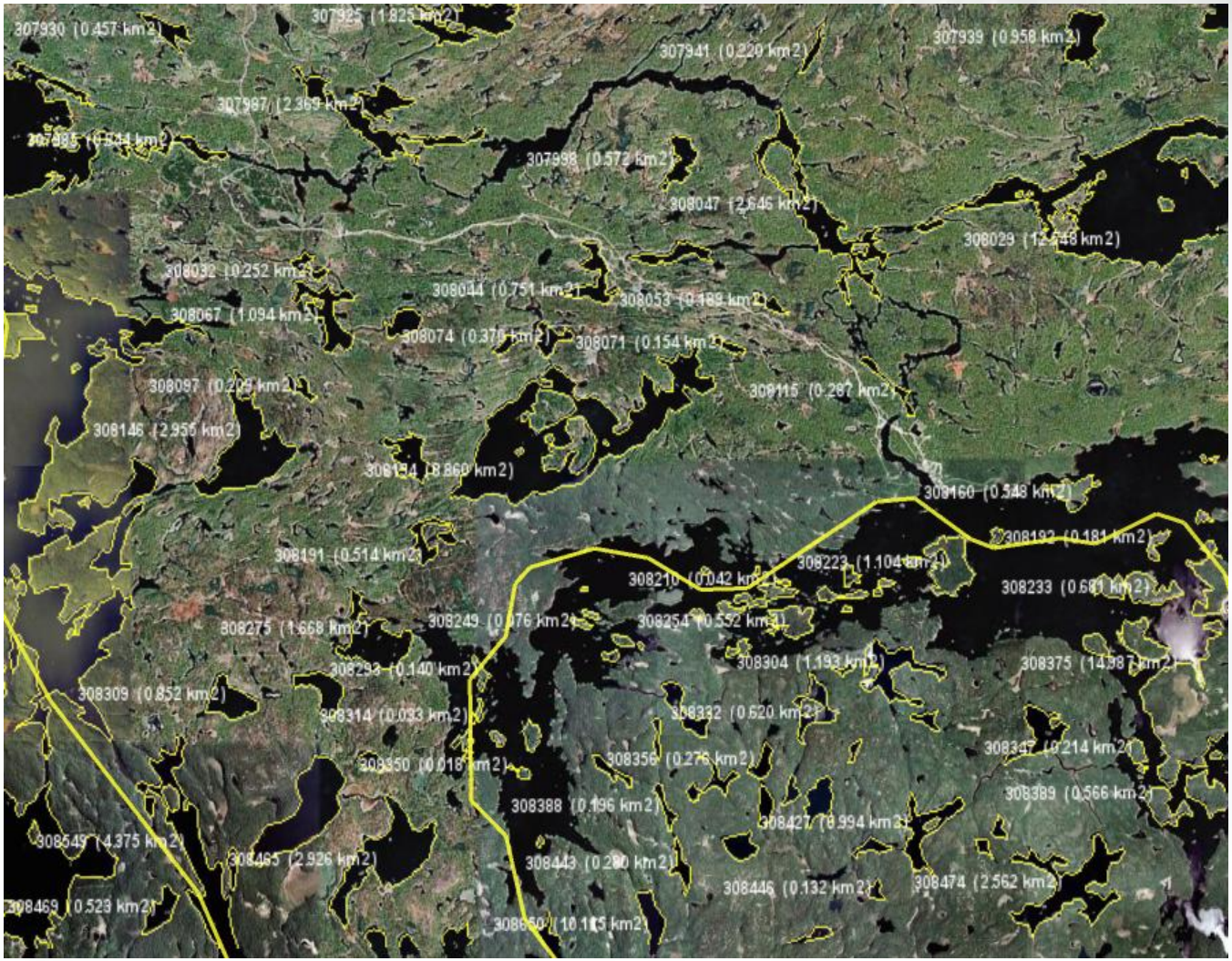
Environment and Water

SWDB Lakes Polygons



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Locating Dams

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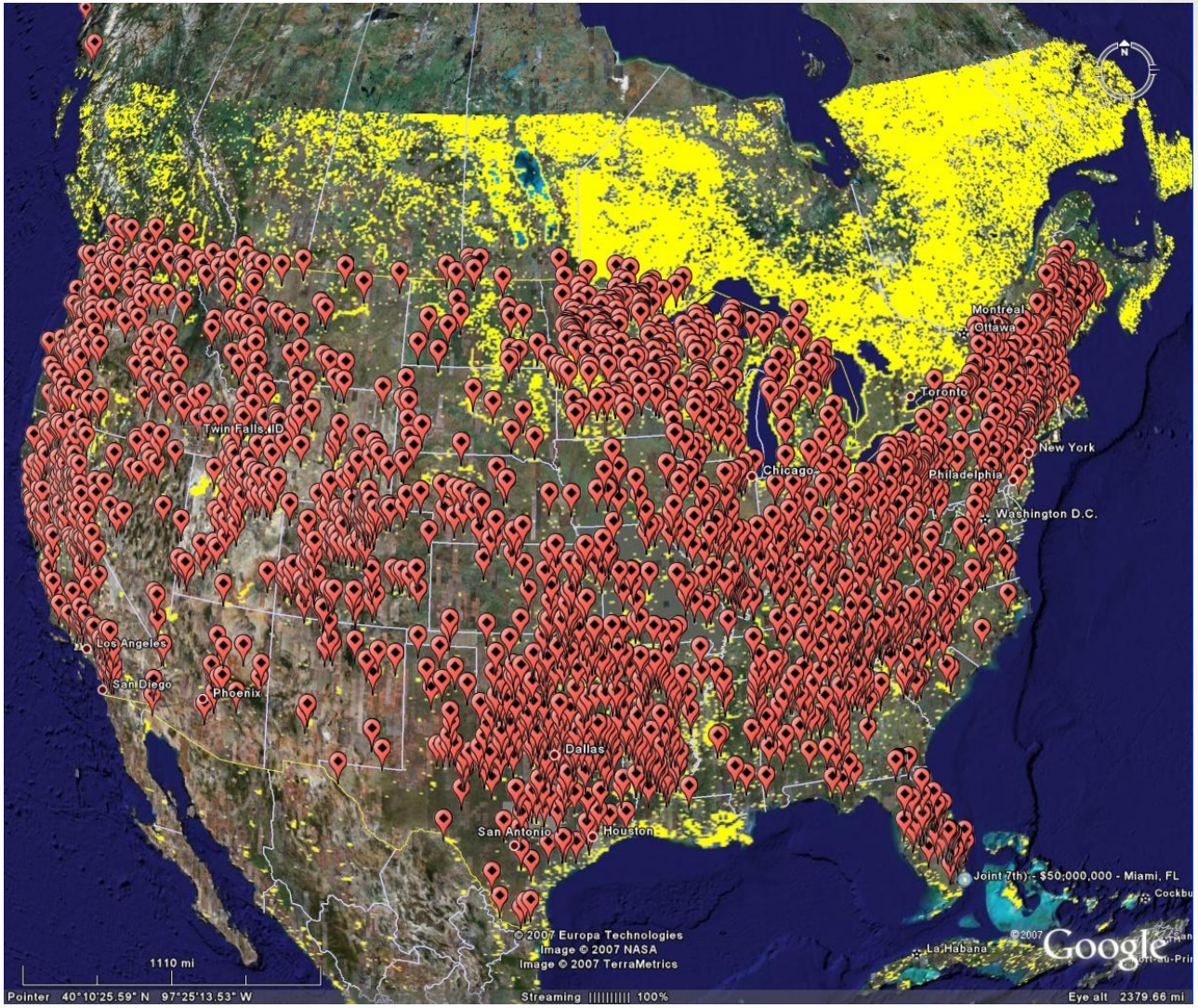
Center for Research on Environment and Water

Co-registered Reservoirs



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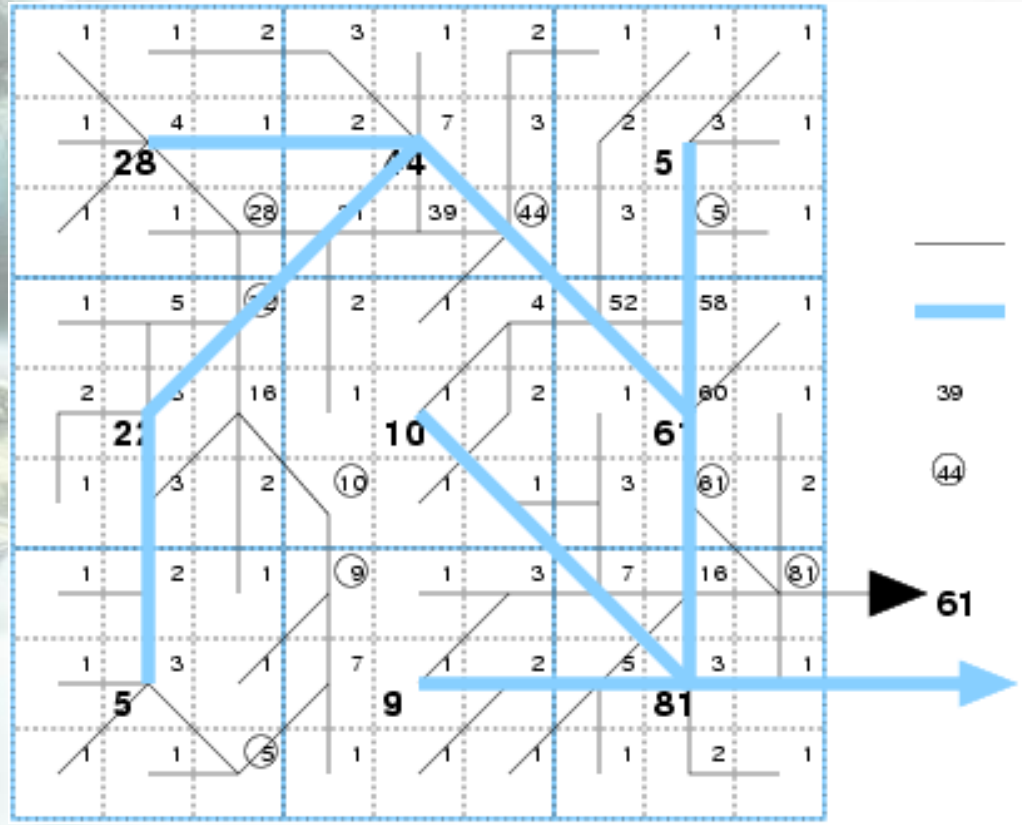
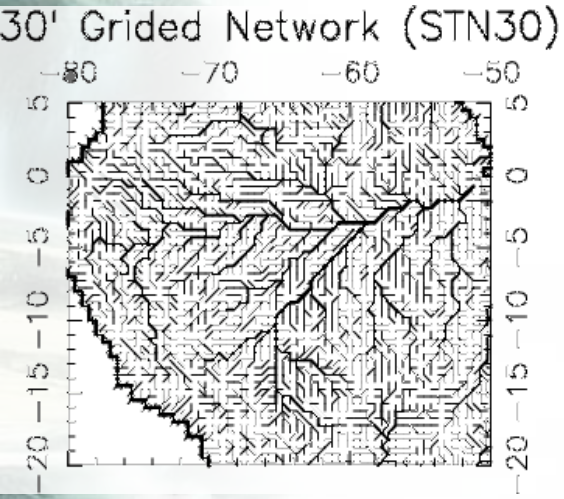
Network Rescaling Algorithm

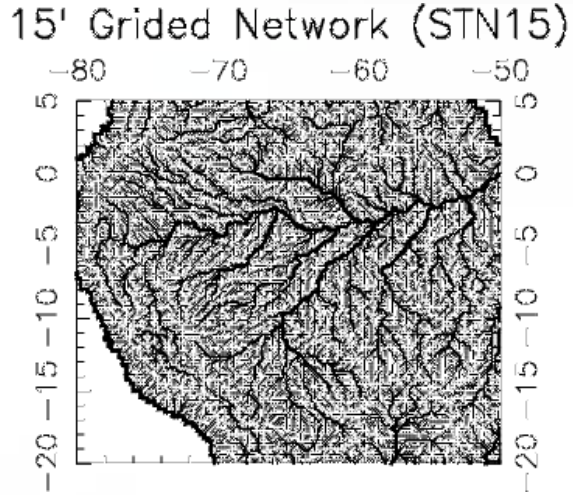


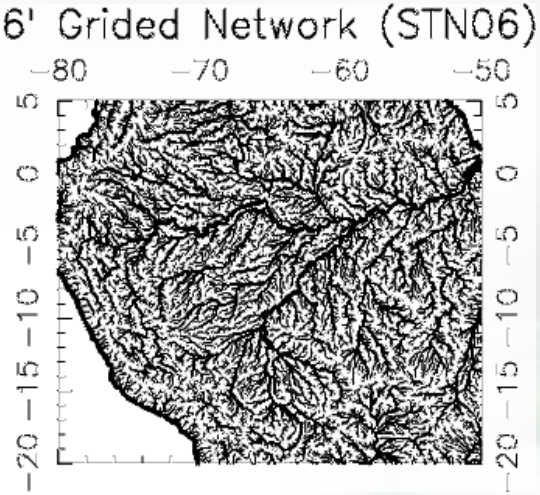
Legend

- Original fine resolution network
- Regridded coarse resolution network
- 39 — Fine resolution drainage area
- (44) — Maximum value of the fine resolution drainage area within the 3x3 kernel
- Aggregated drainage area using maximum operator

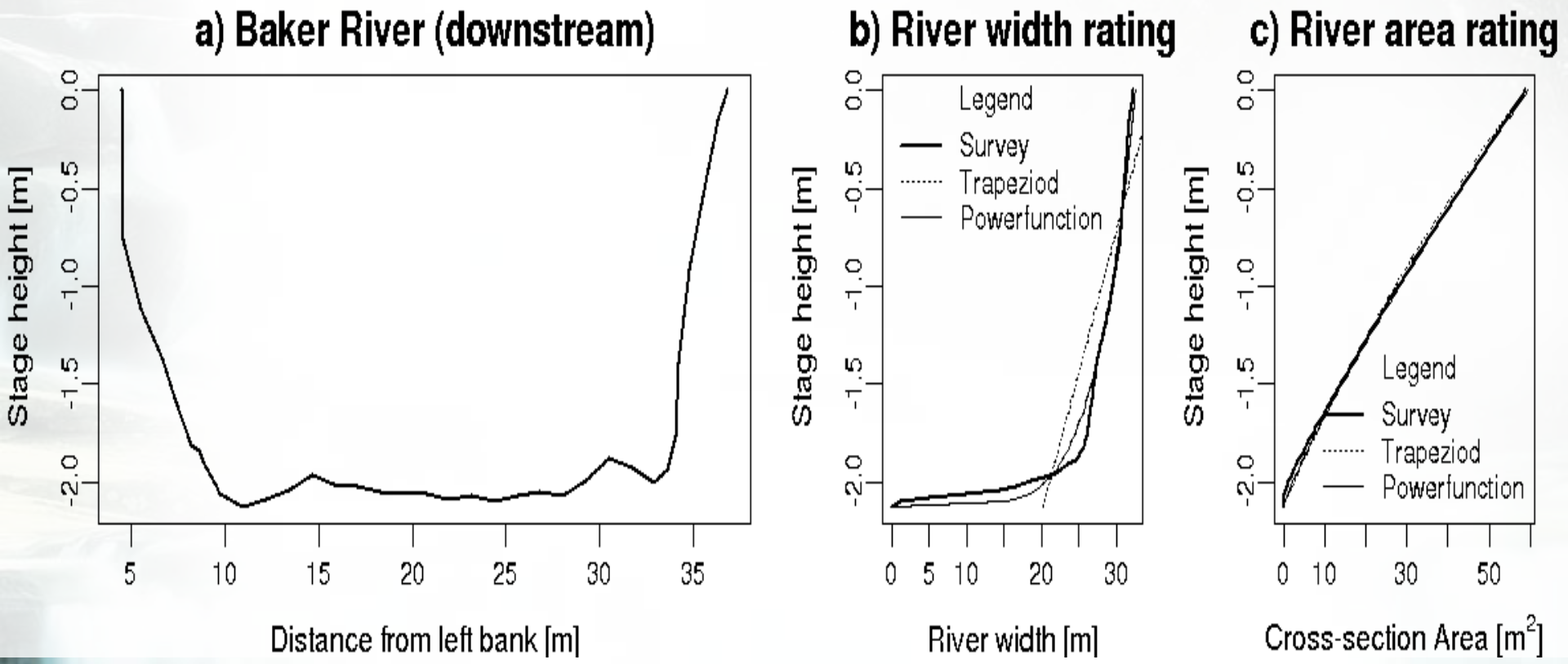
Network Rescaling



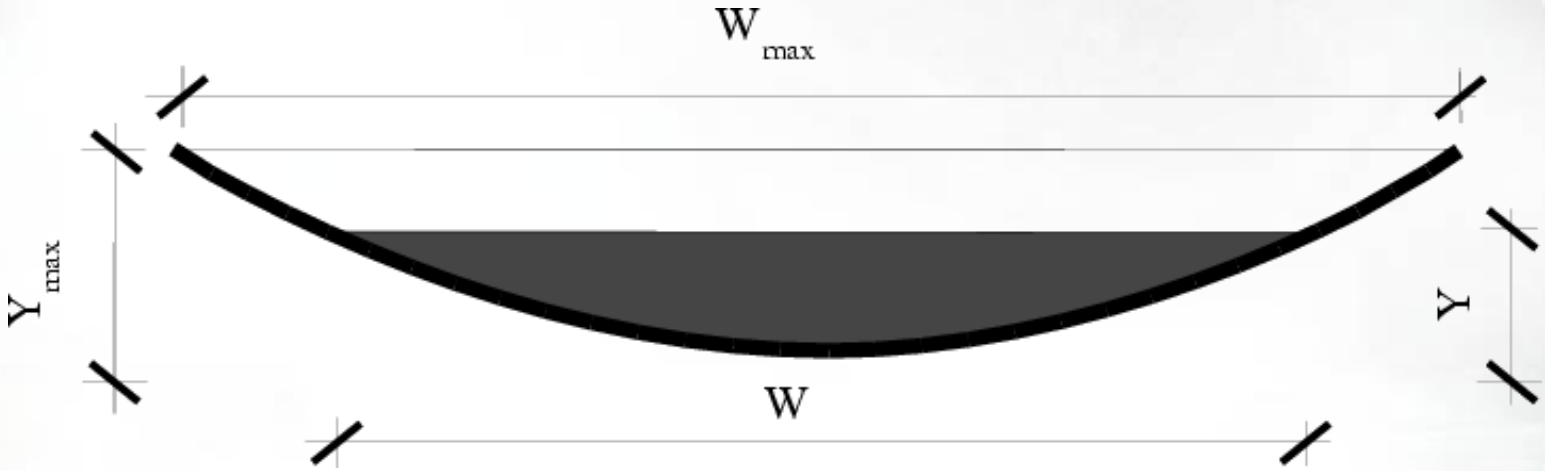




Riverbed Cross-section



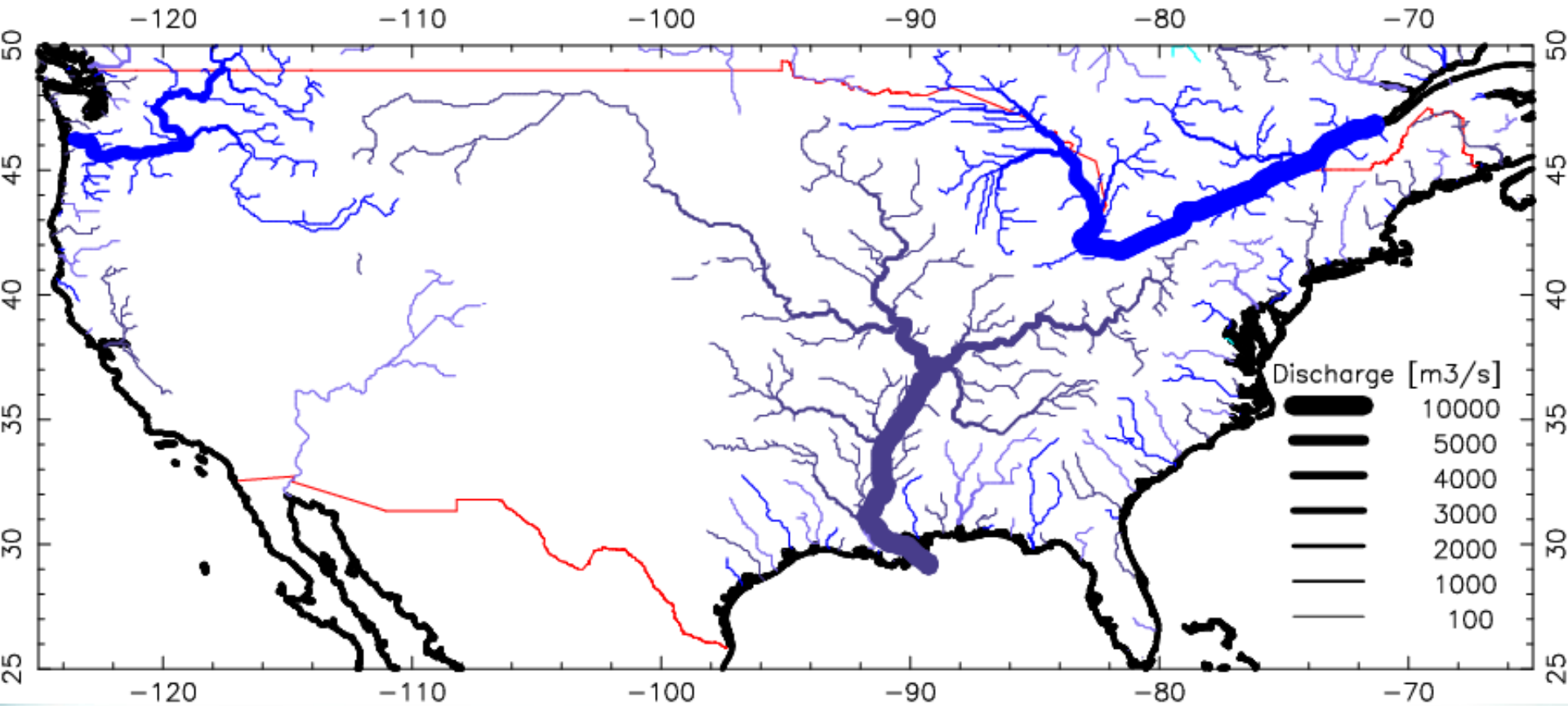
Parabola Equation



$$Y = \alpha W^{\beta}$$

$$\text{陀} = \frac{\beta}{\beta+1} Y$$

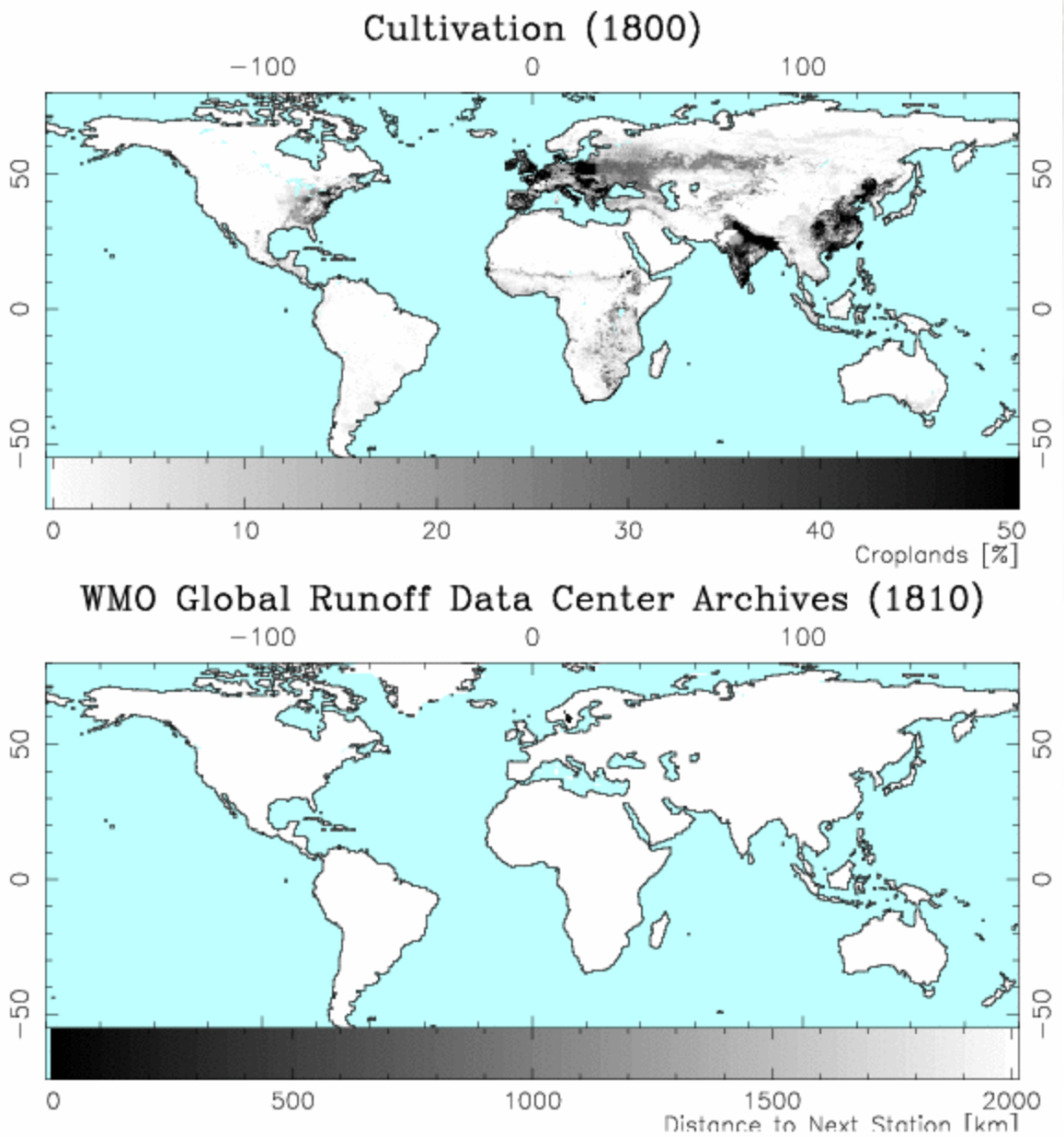
Composite Discharge at 6' Resolution



Global River Volumes and Areas

Continent	Res.	Area [10^3 km^2]					Volume [km^3]			
		Land	Emp.	I.	II.	III.	Emp.	I.	II.	III.
Africa	30'	30,099	72	82	38	47	462	270	227	266
	6'	30,000	89	115	65	72	494	342	269	323
Asia	30'	43,991	94	175	63	84	349	384	279	345
	6'	44,918	118	222	112	124	349	418	299	371
Australasia	30'	9,037	7	20	5	8	22	37	24	32
	6'	9,323	9	19	9	10	17	19	15	18
Europe	30'	9,922	22	57	17	25	55	85	60	76
	6'	10,234	28	65	31	36	58	84	61	75
North America	30'	24,569	44	100	33	45	135	163	119	147
	6'	22,990	54	130	58	68	131	175	124	155
South America	30'	17,945	107	122	48	64	992	586	460	556
	6'	18,136	140	186	87	105	1,143	837	598	747
Total	30'	135,564	346	557	205	273	2,015	1,526	1,171	1,422
	6'	135,602	438	736	362	416	2,191	1,875	1,365	1,690

Land-use change



CREW Center for Research on Environment and Water

Earth System Model Development Challenges

- Increasing data processing need
- Increasing data complexity
- Increasing model complexity
- Heterogenous computer platforms
- Increasing software infrastructure complexity

Modelling Framework Functions

- Spatial domain management and interfacing between different domains (potentially in distributed computing environment)
- Time management (advancing time, calling alarms, etc.)
- Model execution
- Input/Output
- Logging facilities
- Diagnostic/Visualization Hooks

Needed IT Infrastructure

- Metadatabase
- Machine accessible data services
- Data analysis/Modeling framework

New Modeling Framework

- Modules (loaded as plugins)
- Module definitions (parsed from the module plugins)
- Model layout and configuration (via Extensive Markup Language [XML] layout/state file)
- Model framework loads plugins according to state layout file and executes model simulation

Modeling Framework

```
Entering: Discharge
  Entering: Discharge Muskingum
     Entering: Runoff
        Entering: WaterBalance
           Entering: Base flow
              Entering: Infiltration
                 Entering: Water Surplus
                    Entering: Snow Pack Change
                     Leaving: Snow Pack Change
                    Entering: Soil Moisture
                       Entering: PotET Hamon
                          Entering: Day length
                           Leaving: Day length
                        Leaving: PotET Hamon
                       Entering: Intercept
                        Leaving: Intercept
                     Leaving: Soil Moisture
                  Leaving: Water Surplus
               Leaving: Infiltration
              Entering: Irrigation
               Leaving: Irrigation
            Leaving: Base flow
         Leaving: WaterBalance
      Leaving: Runoff
     Entering: Reference Discharge
        Entering: Average NSteps
         Leaving: Average NSteps
        Entering: Accumulate Runoff
         Leaving: Accumulate Runoff
      Leaving: Reference Discharge
   Leaving: Discharge Muskingum
ID  Start_Date                    Variable[      Unit]   Type TStep NStep Set Flux Boundary Output
  0       XXXX                  TEMVegCover[         ]    int  year   365 yes   no       no     no
  1       XXXX                 RootingDepth[        mm]  float  year   365 yes   no       no     no
  2    2000-01               AirTemperature[      degC]  float month    31 yes   no       no     no
  3 2000-01-01                  DailyPrecip[      mm/d]  float   day     1 yes  yes       no     no
  4       XXXX           IrrigationIntensity[        -]  float  year   365 yes   no       no     no
  5       XXXX                FieldCapacity[      mm/m]  float  year   365 yes   no       no     no
  6       XXXX                 WiltingPoint[      mm/m]  float  year   365 yes   no       no     no
  7       XXXX       IrrigatedArea Fraction[        -]  float  year   365 yes   no      yes     no
```

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WaterNet: Concept

Improve and optimize the sustained ability of water cycle researchers, stakeholders, organizations and networks to interact, identify, harness, and extend NASA research results to augment decision support tools.

1. ***Evolve a network of partners:*** identify and analyze partner organizations to define collaboration pathways.
2. ***Routinely identify, prioritize, mine and communicate relevant research products and results.***
3. ***Optimize water cycle partner access*** to research results and products to create a self-sustaining network.
4. ***Analyze and document*** the network effectiveness through metrics, resource estimates and documentation.
5. ***Education and outreach*** is important to help society understand and use the research in every-day application.